PB82-107954

Hourly Diurnal Flow Variations in Publicly-Owned Wastewater Treatment Facilities

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West Chester, PA

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Sep 81

U.S. Department of Commerce
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EPA-600/2-81- 218
September 1981

HOURLY DIURNAL FLOW VARIATIONS IN PUBLICLY-OWNED WASTEWATER TREATMENT FACILITIES

by

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EPA Contract No. 68-03-2775

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CINCINNATI, OHIO 45268

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EPA Form 2350-4 (4-80)
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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/2-81- 218

2.
ORD Report

3. RECIPIENT'S ACCESSION NO.
PB82 107954

4. TITLE AND SUBTITLE
Hourly Diurnal Flow Variations in Publicly-Owned Wastewater Treatment Facilities

5. REPORT DATE
September 1981

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Roy F. Weston, Inc.

8. PERFORMING ORGANIZATION REPORT NO.
W.O. No. 0300-84-03

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Roy F. Weston, Inc., Designers-Consultants
Weston Way
West Chester, Pennsylvania 19380

10. PROGRAM ELEMENT NO.
AZB1B, D.U. B-113, Task 01/B6

11. CONTRACT/GRANT NO.
Contract No. 68-03-2775

12. SPONSORING AGENCY NAME AND ADDRESS
Municipal Environmental Research Laboratory - Cin., OH
Office of Research & Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED
Final, 1979

14. SPONSORING AGENCY CODE
EPA/600/14

15. SUPPLEMENTARY NOTES
Project Officer: Jon H. Bender (513)684-7607

16. ABSTRACT

A survey of 39 sanitary sewer collection systems was undertaken to determine the magnitude of hourly peak flows and to identify parameters most influencing the observed peaks. The significant parameters identified included: industrial contribution, collection system age, depth to groundwater and low lift pre-plant pumping stations. Collection systems with larger industrial contributions were observed to have higher peak flows than those with small industrial contributions. Variations in observed peak flows were exhibited between spring and summer periods in high groundwater and among old-age systems due to infiltration during the spring season. Low lift pre-plant pumping stations, depending upon their capacity and control, can create extremely high peak flows and pulses that do not reflect normal diurnal influent flow patterns. The mean, average peak hourly flow per day for non-industrial collection systems examined, excluding inflow, was found to be 1.23 times the average annual flow. This value did not significantly vary with flow rate; however, the variation around this mean value decreased with increasing flow.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sewers - Sanitary Sewers Sewage Treatment - Sewers Flow Distribution Flow Measurement - Water Flow	Peak Sanitary Sewer Flow	13 B

18. DISTRIBUTION STATEMENT Release to the Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 122
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems: to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; to preserve and treat public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

Hourly diurnal wastewater flow variations reaching the treatment plant affect unit operation performance and, therefore, must be addressed by the plant designer. This report characterizes typical diurnal municipal wastewater flow variations and examines the major dry-weather factors causing them.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

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ABSTRACT

Hourly diurnal flow variations at wastewater treatment plants subject unit operations to fluctuations that influence their performance. These variations are rarely addressed in the design of these facilities.

A survey of 39 sanitary sewer collection systems was undertaken to determine the magnitude of hourly peak flows and to identify the collection system parameters that were most influential in affecting the observed peaks. Significant collection system parameters identified included:

- Industrial Contribution.
- Average Age of the Collection System.
- Depth to Groundwater.
- Low Lift Pre-Plant Pumping Stations.

Collection systems with larger industrial contributions were observed to have higher peak flows than those with small industrial contributions.

Variations in observed peak flows were exhibited between spring and summer periods in high groundwater and among old-age systems due to infiltration during the spring season.

Low lift pre-plant pumping stations, depending upon their capacity and control, can create extremely high peak flows and pulses that do not reflect normal diurnal influent flow patterns.

The mean, average peak hourly flow per day for non-industrial collection systems examined, excluding inflow, was found to be 1.23 times the average annual flow. This value did not significantly vary with flow rate; however, the variation around this mean value decreased with increasing flow.

This report was submitted in fulfillment of Contract No. 68-03-2775 by Roy F. Weston, Inc., under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period August 1979 to December 1979, and work was completed as of December 1980.

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(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE: 1980-660-539
TYPING GUIDE SHEET

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SECTION 1

INTRODUCTION

Hydraulic and organic variations of sewage flow at publicly-owned wastewater treatment works (POTWs) represent design items that the engineer must address before he undertakes his process and hydraulic design. In the absence of monitored flow, traditional design practice for the hydraulic sizing of unit wastewater treatment processes has relied upon the application of peaking factors to estimate peak sanitary design flows. These factors are commonly defined as the ratio of peak flow to average flow, and have been presented in terms of fixed values[1] or as a function of influent flow rates or collection system population.[2,3] To estimate the total peak flow, the designer must add components for infiltration and inflow to the total peak sanitary flow. More recent investigations have sought to develop empirical equations to facilitate the prediction of extreme peak flows that include both dry-weather and wet-weather events.[4,5]

Although it is generally agreed that the influence of peaking on treatment process efficiency can be significant, little if any agreement exists on the degree to which peaking affects performance, nor are there appropriate guidelines for process design modifications that should be associated with these variations. Organic concentrations have been shown to increase with increasing flow rates over the course of a typical dry-weather day,[6,7] resulting in compounded organic loads during the dry peak flow periods. Yet, organic loading designs are normally based upon average flow and average organic concentrations.

The characteristics of the collection system are largely responsible for the magnitude and variations exhibited in influent wastewater treatment plant flows. The difficulty associated with correlating collection system parameters with peaking and variation in flow has had limited previous investigation in this area. As a result, peaking has been addressed as a function of flow rate or equivalent population.[8,9,10]

Since peaking design consideration is presently left to the design engineer and his best engineering judgment to account for hydraulic and organic variations, additional investigations depicting the magnitude of peaks and the influence of various collection system parameters are warranted. This report characterizes typical hydraulic flow variations entering municipal wastewater treatment plants and examines the major dry-weather factors causing them.

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SECTION 2

CONCLUSIONS

Sanitary sewer collection system factors found to have the most impact on the average hourly peaking factor include the percentage of the total flow to the POTW contributed by industries or institutions, the average age of the system, the depth to groundwater, and the impact of low lift pre-plant pumping stations.

Collection systems with industrial or institutional flow contributions greater than 40 percent were found consistently to have higher daily peak flows than those below 40 percent. Industrial flows can also be seasonal with flows during the industrial season, resulting in higher peaking factors. Peak flow hours of the day tended to occur at earlier hours in industry-dominated systems.

Non-industrial collection systems with an average age greater than 25 years and high groundwater tables are more susceptible to infiltration and, as a result, exhibit higher peaking factors during the spring or infiltration season.

The mean average hourly peak flow for non-industrial systems, excluding inflow, was found to be 1.23 times the annual average daily flow ($PF_A = 1.23$) and did not vary significantly with the average collection system flow rate.

As collection system flow rate increases, variations around the mean value decrease. The mean flow estimate for larger systems has greater reliability than that for smaller systems.

Individual average hourly peaking factor values for the spring varied up to 1.5 times those during the summer for old-age systems with high groundwater tables.

The mean average hourly peaking factor for industry-dominated systems was found to be 1.32 ($PF_A = 1.32$). The industrial season mean average hourly peaking factor was found to be 1.59.

The peak hours for non-industrial collection systems fell predominantly between 10 a.m. and 4 p.m. during the course of the day. Industrial and institutional system peaks fell largely between 10 a.m. and 2 p.m.

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The mean maximum hourly peaking factor for non-industrial collection systems was found to be 1.70 ($PF_M = 1.70$) for 20 days of data. Maximum hourly peaking factors were calculated as high as 2.82 during the 20-day sample period. Maximum hourly peaking factors increased with increasing sample time periods.

Instantaneous maximum peaking factors for low lift pump-dominated systems ranged from 1.3 to 4.7, while the minimum instantaneous flow factors varied from 0 to 0.8. Low lift pumping stations designed to provide the required head and capacity without consideration of peaking effects can be the dominant factor influencing peak-flow magnitudes.

SECTION 3

RECOMMENDATIONS

Several factors significantly affect daily dry-weather influent flow peaks and fluctuations at publicly-owned treatment works. The factors below must be addressed in any study seeking to characterize influent wastewater so that unit operations of the treatment plant can be properly designed and operated.

Industrial wastewater discharge schedules, as well as magnitude and make-up, should be defined to determine the wastewater impact on treatment plant performance. When industrial wastewater contributes greater than 40 percent of the total flow to the POTW, careful assessment should be made of its impact on peak flows.

Surveys characterizing influent wastewater from older (>25 year) non-industrial sanitary sewer collection systems should pay particular attention to potential seasonal infiltration from high groundwater tables.

Low lift pre-plant pumping station operation can be the single-most important factor influencing hydraulic diurnal flow variations experienced at the POTW. Pump capacity and control should be taken into account in the design of new POTW's or in the investigation of performance problems in existing facilities.

Although this report primarily addresses hydraulic flow variations at the POTW, it is noted that wastewater constituent characteristics also vary. Wastewater hydraulic and concentration measurements must both be made to properly characterize the total mass loading entering the treatment plant.

SECTION 4

INVESTIGATIVE PROCEDURES

OBJECTIVE

Typical diurnal variations in influent flow are depicted by the wave form presented in Figure 1. The flow variation is characterized by two peaks, resulting from morning and early evening water usage, and decreasing late night and early morning flows. The maximum flow of the diurnal flow period is labeled "peak hourly flow" in Figure 1. The time of occurrence, magnitude, and ability to differentiate the individual peaks is dependent upon the individual collection system characteristics or parameters.

Variations in the wave form of any given collection system can be expected to occur on a day-to-day basis. This can take the form of time lags or advances in the wave form or increases or decreases in observed peaks. This latter variation is depicted in Figure 2, which presents a sample diurnal flow variation as a function of flow ratio (defined as the actual flow divided by the average flow) and the average, maximum, and minimum values that can be anticipated over the course of the day.

Systems with excessive inflow can be expected to exhibit wave forms and peak values in response to storm events and not normal diurnal flow patterns. These are not included in this report.

Current process design practices which size systems on the basis of annual average flows and ignore diurnal flow patterns (Figure 2) subject the wastewater treatment unit operations to morning flows which are less than design, followed by flows which are greater than design. In addition, depending upon the season of the year, excess industrial flow or infiltration can shift the flow ratio either up or down, creating a seasonal variation of the typical diurnal pattern. Recent investigations have highlighted the importance of such seasonal variation in design.[10]

The purpose of this investigation was to establish both the magnitude of diurnal hourly peaking factors and the collection

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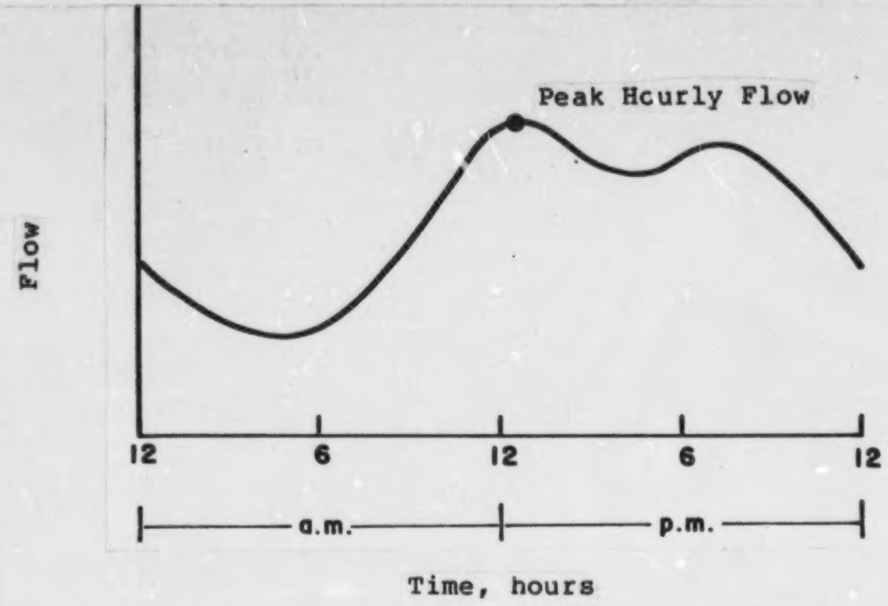

Figure 1. Typical diurnal flow pattern.

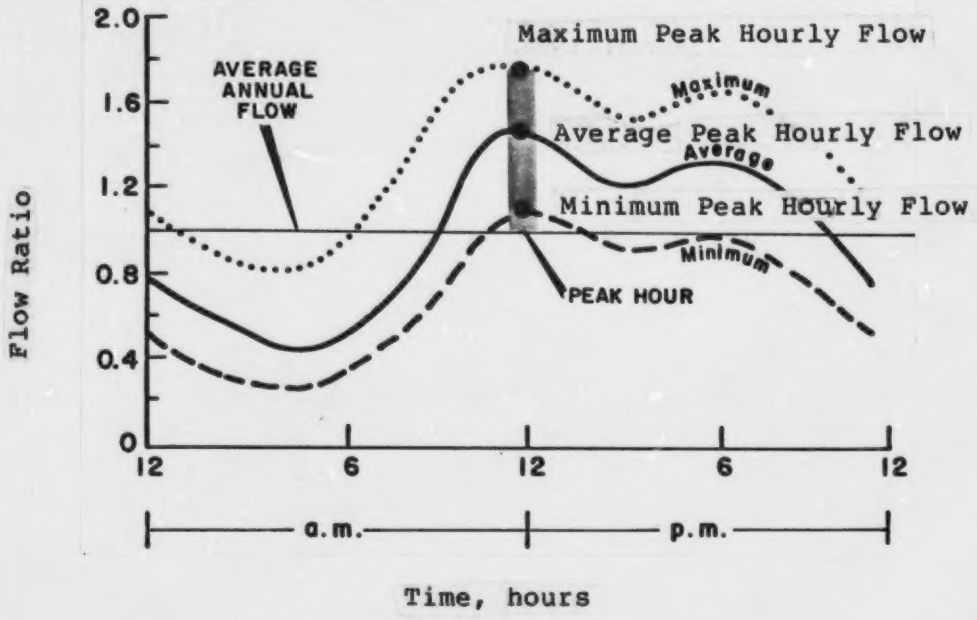

Figure 2 Average maximum and minimum diurnal variations.

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system parameters which exhibit the greatest influence on peaking for typical diurnal flow (excluding inflow).

DEFINITIONS

In order to facilitate communication, a set of definitions for both peaking and collection system parameters was established for use throughout the study. A complete list of all definitions is presented in the Glossary.

Peaking Factor

Peaking in wastewater treatment facilities, defined in terms of a peaking factor, can be expressed in numerous ways. For example, peaking can be expressed as an instantaneous peak, a maximum peak hour, an average peak hour, a minimum peak hour, a peak four hours, an average peak four hours, etc. Much of the early literature and current design manuals[2] fail to differentiate among peaking factors; hence, it is not known whether the peaking factor represents an instantaneous peak, an hourly peak, a daily peak, or some other duration of time.

A peaking factor is a flow ratio, defined as follows:

$$\text{Peaking Factor} = \frac{\text{Peak Flow}}{\text{Average Flow}}$$

Both the peak flow and the average flow are defined in the same units.

Peak Flow

Peak flow is normally expressed in units of million gallons per day (mgd). Four variables must be defined in describing peak flow. These include the peaking duration, the peaking period, the sample time period, and the sample analysis.

The peaking duration -- the unit of time in which the peak is being measured (e.g., instantaneous peak; peak 15 minutes; peak hour; peak four hours; peak day).

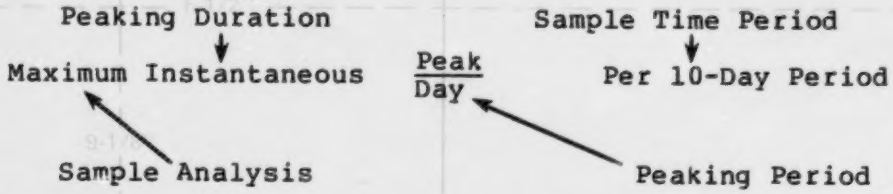
The peaking period -- the time interval over which the peak duration is being composed (e.g., peak hour/day; peak hour/month; peak hour/year).

The sample time period -- the time interval from which the data for calculating the peaking factor is obtained (e.g., peak hour/day from 10 days of data).

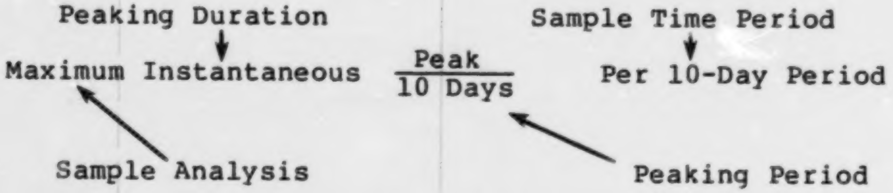
The sample analysis -- the type of statistical approach used in assessing the data. Three approaches are readily identified, as follows:

1. maximum value -- the highest single value of the samples taken.
2. average value -- the average value of the samples taken.
3. minimum value -- the lowest single value of the samples taken.

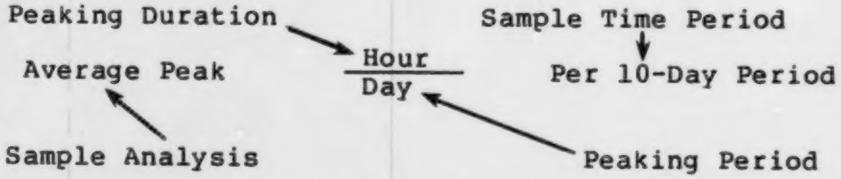
In order to define the peak flow, each of the above variables must be described; for example, the maximum instantaneous flow observed in each day from ten days of data would be reported as:



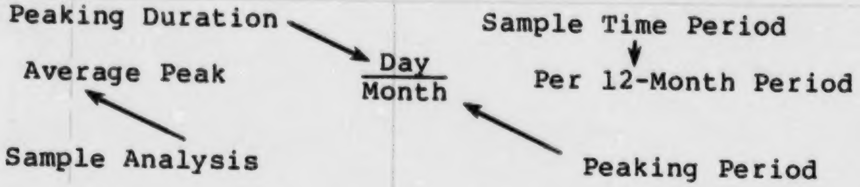
This value represents the single highest instantaneous value observed in 10 days of data and could also be reported as:



The average peak hourly flow per day derived from ten days of flow data is found when flow measured each hour of the day is averaged over ten days, and the average peak hourly flow is selected from the resulting average diurnal flow curve (see Figure 2). The peak flow would be reported as:



The average peak daily flow per month derived from one year of flow data is found when flow measured each day of the month is averaged over 12 months, and the average peak daily flow is selected from the resulting average monthly flow curve. The peak flow would be reported as:



Without adequately identifying the above factors in presenting a peak flow, the exact nature of the value is not defined. For example:

- Without defining the peaking duration, does the peak flow refer to the instantaneous flow, peak hourly, or peak daily flow?
- Without defining the peak period, does the peak flow refer to the peak flow observed during a day, or the peak flow observed during one week?
- Without defining the sample time period, was the peak flow value derived from one day's data, 10 day's data, or one year's data?
- Finally, one must define whether the peak flow refers to an extreme (maximum or minimum) value or an average of observed values.

It follows by definition that these same factors must be identified for a peaking factor to adquately define it.

Average Flow

The denominator of a peaking factor normally contains the annual average daily flow (ADF); however, when assessing limited amounts of data (i.e., 10 days), it is possible to utilize the average flow during this limited time interval as the denominator. For purposes of definition, peaking factors utilizing annual ADF in their denominator are referred to as the Annual Peaking Factor; those using limited amounts of data (less than one year) to calculate average flows are referred to as the Sample Peaking Factor. Average flows are normally expressed in units of mgd.

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Annual Peaking Factors are sensitive to seasonal variations. For example, if an Annual Peaking Factor is defined during a spring period when groundwater tables are high and infiltration increases the peak flow, the Annual Peaking Factor will also increase.

Sample Peaking Factors which utilize average flows calculated over a limited time period would behave differently. For example, during periods of high infiltration, the average flow would normally be expected to increase, resulting in decreasing Sample Peaking Factors.

Since facility design normally involves the use of annual average daily flow, Annual Peaking Factors which define flow relative to this design value are more meaningful for design and have been used throughout this report. All definitions are summarized in Table 1.

Collection System Parameters

Collection system parameters identified for investigation included the following:

Annual Average Daily Flow --

This parameter is expressed as mgd (million gallons per day).

Population --

Population was defined as the number of people in the service area.

Industrial Contribution --

This was expressed as percent of flow to the POTW from industries and institutions in the service area.

Average Annual Rainfall --

This was the average annual rainfall in inches.

Topography --

The topography was expressed as flat, moderate/rolling, or steep.

Soil Type --

The soil type was expressed as predominantly clay, predominantly sand, or mixture.

TABLE 1. DEFINITIONS: PEAKING FACTORS

Peaking Factor

1. Annual Peaking Factor (APF) $= \dfrac{\text{Peak Flow}}{\text{Annual Average Daily Flow (ADF)}}$

2. Sample Peaking Factor (SPF) $= \dfrac{\text{Peak Flow}}{\text{Average Sample Time Period Flow}}$

Peak Flow

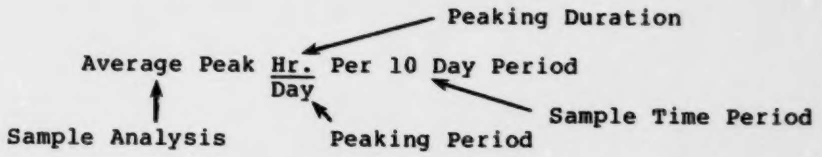
3. Peaking Duration: Unit of time which the peak represents (peak 15 minutes; peak hour; peak day).

4. Peaking Period: The time period over which the peak period is compared (peak hr/day; peak day/year).

5. Sample Time Period: The period of time from which the data is assessed.

6. Sample Analysis:
   - Maximum Value: Maximum value in the sample time period.
   - Average Value: Average value in the sample time period.
   - Minimum Value: Minimum value in the sample time period.

7. Peaking Factor Examples:



Average Flow

8. Annual Average Daily Flow (ADF): The annual volume of influent treatment plant wastewater divided by 365 days, normally expressed in mgd.

9. Average Sample Time Period Flow: The volume of influent treatment plant wastewater during the sample time period divided by the number of days in the sample time period.

Shape of Collection System --

This parameter described the layout of major interceptors and is expressed as clustered, nucleated, or narrow.

Groundwater Table --

The groundwater table was expressed as "low" for a collection system in which sewers were always above the groundwater table; as "high" for a collection system in which the elevation of the groundwater table periodically exceeded that of the sewers; and as "mixture", where partial periodic inundation was identified.

Average Age --

This parameter was expressed as an approximate indication of the age of the collection system.

Number of Pumping Stations --

This was the number of lift stations in the collection system.

Bypass --

This parameter was used to indicate the presence of a bypass line before the influent flow meter at the POTW (expressed as "yes" or "no").

It is possible to define other collection system parameters which may influence peaking, and the above parameters could be redefined into a more quantitative format; however, within the scope of this investigation, the designations presented were judged adequate.

Collection System Parameter Impacts

Each collection system parameter can influence peaking and hydraulic diurnal variations. Quantitatively, this influence is presently undefined, but, in general, the impact of each parameter in the past has been assumed to follow the trends indicated below:

Annual Average Flow and Population --

Larger collection systems, flow rates, and populations are associated with lower peaking factors.

Percent Industrial Contribution --

Depending upon the types of industry, these impacts are expected to exhibit seasonal variations, and larger contributions can be expected to increase peaking factors.

Topography --

Steep systems can be expected to enhance peaking, while flat systems are expected to minimize peaking. Moderate/rolling system impacts are undefined.

Average Annual Rainfall --

Higher average annual rainfall would normally be equated with lower peaking factors (i.e., greater ADF with unaffected dry weather peak flow).

Soil Type --

The greater the soil permeability, the greater potential infiltration, and the greater the expected peaking factor.

Shape of Collection System --

Clustered systems are expected to exhibit higher peaking factors than nucleated or narrow systems, due to the additive flow reaching the facility from different parts of the collection system at approximately the same time.

Groundwater Table --

High groundwater tables are expected to increase both the infiltration rates and the Annual Peaking Factor.

Average Age --

Average age is a difficult parameter to quantify, since most collection systems are built in phases over a number of years. However, the older the system, the more inflow/infiltration expected, and higher peaking factors, as well.

Number of Pumping Stations --

The influence of the number of pumping stations is uncertain and highly dependent upon the individual system. In many cases, however, one would expect that a large number would become a controlling factor in peaking and the diurnal wave form.

Bypass --

A bypass can be expected to limit observed peaking factors; however, under normal dry-weather flow conditions, a bypass would have little influence.

METHODOLOGY

Data Sources

An initial survey of 145 POTW's was undertaken to identify those separate sanitary sewer systems: with annual average daily flows between 0.05 and 100 mgd; with properly calibrated diurnal influent flow recorders and records of these flows; and with sufficient information on collection system parameters.

Sanitary sewer systems were further selected based upon the need both to identify sewer systems with an equal distribution of collection system parameters and to establish, to the extent possible, an equal geographic distribution of facilities investigated throughout the country.

Table 2 lists the 145 POTW's originally included in the survey. Preliminary screening of the 145 POTW's using the above collection system criteria resulted in 39 systems being selected for study. Their collection system parameters are listed in Table 3.

Figure 3 presents the geographic distribution of the 39 selected POTW's throughout the United States, with the I.D. Number keyed to Table 3.

Continuous flow data from each of the 39 facilities was obtained for 10 days during the spring and 10 days during the summer (i.e., 2-5 consecutive weekdays). For one facility, an entire year record was obtained for analysis.

Flow data during the spring and summer were obtained to assess their seasonal differences between peaking values observed. Annual records from one facility were obtained to determine how well small sample time periods represent larger periods. Flow data for the spring and summer periods were reviewed and systems where inflow predominated were eliminated from the analysis. The annual data, however, were not screened for inflow events. In addition, individual collection systems which were found to be partially combined or to contain equalization basins prior to influent into the facility were eliminated from further analysis.

TABLE 2. POTW'S INVESTIGATED

I.D. NO.	STATE	NAME	I.D. NO.	STATE	NAME	I.D. NO.	STATE	NAME
1	PA	Lower Salford	50	CO	Broomfield WWTP	99 *	NY	Ocean Beach, Fire Island
2	NJ	Hightstown	51	KS	Lawrence WWTP	100 *	NY	Bayport Garden Apartments
3 *	NJ	East Windsor	52 *	KS	Manhattan	101 *	NY	Dorado Garden Apartments
4 *	MD	Hagerstown	53 *	MI	Mt. Clemens STP	102 *	NY	Parkland III
5 *	MD	Maryland Correction Institute	54 *	MI	Ypsilanti Township WWTP	103 *	NY	Riverhead STP
6 *	MD	Funkstown	55 *	MO	Shoal Creek WWTP	104 *	NY	Greenport STP
7 *	MD	Smithburg	56 *	NV	Reno Sparks STP	105	MN	Anoka (M-300)
8 *	MD	Halfway	57	SD	Watertown STP	106	MN	Bayport (M-608)
9	MD	Richlyn Manor	58	TX	Guadalupe-Blanco River	107	MN	Blue Lake (M-400)
10	CT	City of West Haven	59	TX	Midland WWTP	108	MN	Salvage (M-406)
11 *	KY	Louisville	60 *	TX	Odessa STP	109 *	IN	Lebanon
12	GA	Pole Bridge	61 *	UT	Sandy Suburban STP	110 *	NJ	Haddon Heights (SA-26)
13	GA	Honey Creek	62 *	WA	Lacy-Olympia-Tumwater Thurston County STP	111 *	NJ	Osage (SA-39)
14	GA	Shoal Creek	63 *	WY	Crow Creek WWTP	112 *	NJ	Ashland (SA-38)
15 *	LA	City of Kenner	64	NY	Belgrave	113 *	NJ	Winslow (SA-40)
16 *	LA	City of Slidell	65 *	NY	Great Neck Sewer District	114 *	NJ	Clementon (SA-17)
17 *	LA	City of DeQuincy	66 *	NY	Great Neck Village	115 *	NJ	Brooklawn (SA-5)
18 *	LA	Gramercy	67 *	NY	Port Washington	116 *	NJ	Chews Landing (SA-21)
19 *	LA	Town of Lutcher	68 *	NY	Roslyn	117 *	NJ	Mardela Manor (SA-22)
20 *	LA	City of Springhill	69 *	NY	Glen Cove	118 *	NJ	Blackwood (SA-23)
21 *	LA	City of Opelousas	70 *	NY	Oyster Bay	119 *	NJ	Cataline Hills (SA-24)
22 *	LA	City of Winnfield	71	NY	Bay Park	120 *	CA	Fountain Valley STP #1
23 *	LA	City of Amite	72 *	NY	Cedarhurst	121 *	CA	Huntington Beach
24 *	LA	City of Ponchatola	73	NY	Freeport	122	MN	Chaska
25 *	LA	City of Marksville	74 *	NY	Lawrence	123	MN	Maple Plain
26 *	MI	Walled Lake	75	NY	Long Beach	124 *	MO	Bonne Terre East
27 *	VA	City of Roanoke	76	NY	West Long Beach	125	IN	Carmel North
28	OH	Lebanon	77 *	NY	Port Jefferson Sewer District #1	126	IN	Carmel South
29	OH	Toledo	78 *	NY	Holbrook Sewer District #2	127	MI	East Tawas
30	IL	Greater Peoria	79 *	NY	Southwest Sewer District #3	128 *	MI	Bad Axe
31 *	IL	Dixon	80 *	NY	Birchwood Sewer District #4	129 *	MO	Bowling Green
32	IA	Ames	81 *	NY	Strathmore Sewer District #5	130 *	MD	Platte City
33	WA	Pullman	82	NY	Kings Park Sewer District #6	131	MO	North Kansas City
34 *	MT	Bozeman	83 *	NY	12 Pine Sewer District #7	132 *	CA	San Jacinto
35	NJ	Gloucester	84 *	NY	Woodside Sewer District #8	133 *	CA	Sunny Mead
36 *	NJ	Stratford STP	85 *	NY	Strathmore Ridge Sewer District #9	134 *	CA	Sun City
37 *	NJ	Lindenwold STP	86 *	NY	Stony Brook Sewer District #10	135 *	CA	Rancho California
38 *	CA	California Institute For Women	87 *	NY	Selden Sewer District #11	136 *	CA	Palmdale
39 *	CA	Bear Creek STP	88 *	NY	Farmingdale Agricultural College	137 *	CA	Lancaster
40 *	CA	Rancho Bernardo STP	89 *	NY	Republic Aviation	138 *	WI	Johnson Creek
41 *	CA	Willits STP	90 *	NY	Brookhaven National Laboratories	139 *	WI	Founddulac
42 *	TX	Ingelside WWTP	91 *	NY	Leisure Village, Shoreham	140	WI	Beloit
43	UT	Saline STP	92 *	NY	Patchogue Sewer District	141 *	IL	Roxana
44 *	CA	Chino Basin Municipal Water Plant	93 *	NY	Selden Sanitary Corporation	142 *	IL	Addison South
45 *	CA	Laguna WWTP	94 *	NY	Brookhaven Mental Hospital	143 *	IL	Bensenville
46 *	CA	Rossmore Sanitation, Inc.	95	NY	Huntington STP	144 *	MO	Tawas City
47	CA	San Luis Rey WWTP	96 *	NY	Northport Veterans Hospital	145	CA	La Salina
48 *	CA	Valley Community Service District STP	97 *	NY	Northport Village STP			
49 *	CO	Upper Thompson WWTP	98 *	NY	Suffolk State School			

*Not included in this analysis.

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TABLE 3. COLLECTION SYSTEM PARAMETERS FOR SELECTED POTW'S

I.D. NO.	STATE	NAME	AVERAGE ANNUAL FLOW (MGD)	POPULATION	PERCENT INDUSTRIAL CONTRIBUTION	AVERAGE ANNUAL RAINFALL (IN.)	TOPOGRAPHY	SOIL TYPE	SHAPE	GROUNDWATER TABLE	AVERAGE AGE (YRS.)	NO. OF PUMPING STATIONS	BYPASS
1	PA	Lower Salford	0.36	4,500	21	40	Flat	Clay	Nucleated	Deep	15	2	Yes
2	NJ	Hightstown	0.84	6,500	12	43	Flat	Sand	Cluster	Shallow	48	3	No
9	MD	Richlyn Manor	0.07	1,000	0	44	Rolling	Clay	Narrow	Shallow	18	1	No
10	CN	City of West Haven	7.30	57,000	≤5	43	Steep	Clay	Cluster	Shallow	39	15	No
12	GA	Pole Bridge	1.58	23,000	15	48	Rolling	Clay	Narrow	Shallow	45	1	No
13	GA	Honey Creek	0.42	5,000	10	48	Steep	Clay	Narrow	Shallow	45	2	No
14	GA	Shoel Creek	2.69	29,000	5	48	Rolling	Clay	Narrow	Shallow	45	1	Yes
28	OH	Lebanon	1.40	9,500	0	32	Rolling	Mixture	Nucleated	Deep	33	0	Yes
29	OH	Toledo	78.00	420,000	28	31	Flat	Mixture	Nucleated	Shallow	60	34	Yes
30	IL	Greater Peoria	30.00	170,000	31	35	Steep	Clay	Narrow	Deep	50	3	Yes
32	IA	Ames	5.00	45,000	40	32	Steep	Clay	Cluster	Deep	24	10	Yes
33	WA	Pullman	3.10	24,000	95	20	Rolling	Clay	Cluster	Shallow	40	1	Yes
35	NJ	Gloucester	1.60	14,500	10	40	Flat	Mixture	Nucleated	Shallow	70	8	Yes
43	UT	Salina STP	0.35	2,200	50	8	Steep	Clay	Cluster	Deep	20	0	No
47	CA	San Luis Rey WWTP	3.60	33,000	15	12	Rolling	Sand	Nucleated	Deep	49	13	No
50	CO	Broomfield	2.50	23,000	≤5	14	Moderate	Clay	Cluster	Deep	20	2	No
51	KS	Lawrence WWTP	5.00	55,000	40	35	Rolling	Clay	Cluster	Shallow	25	21	No
57	SD	Watertown	2.70	18,000	≤5	21	Rolling	Sand	Nucleated	Shallow	75	37	No
58	TX	Guadalupe-Blanco River	5.00	58,000	≤20	36	Flat	Clay	Cluster	Deep	84	14	No
59	TX	Midland	6.20	80,000	≤5	15	Flat	Sand	Nucleated	Deep	25	0	Yes
64	NY	Belgrave	1.59	13,000	≤5	42	Moderate	Clay	Cluster	Mixture	45	0	No
71	NY	Bay Park	63.90	560,000	≤10	42	Flat	Mixture	Narrow	Shallow	35	21	No
73	NY	Freeport	4.20	41,000	≤10	42	Flat	Sand	Narrow	Shallow	45	5	No
75	NY	Long Beach	6.90	34,300	≤ 5	38	Flat	Sand	Narrow	Shallow	70	3	No
76	NY	West Long Beach	0.72	5,000	0	38	Flat	Sand	Narrow	Shallow	50	3	No
82	NY	Kings Park	0.83	13,000	90 Hospital	42	Rolling	Sand	Cluster	Deep	45	2	No
95	NY	Huntington STP	1.80	19,000	≤5	42	Moderate	Mixture	Cluster	Shallow	62	0	No
105	MN	Anoke	1.90	21,800	28	27	Moderate	Sand	Cluster	Deep	60	14	No
106	MN	Bayport	0.50	2,100	50	27	Steep	Mixture	Narrow	Mixture	40	2	No
107	MN	Blue Lake	13.00	115,000	15	27	Rolling	Mixture	Nucleated	Mixture	18	198	No
108	MN	Salvage	0.42	3,000	27	27	Steep	Clay	Narrow	Shallow	40	3	No
122	MN	Chaska	0.85	7,000	12	27	Rolling	Clay	Cluster	Shallow	30	1	No
123	MN	Maple Plain	0.24	1,400	50	27	Rolling	Clay	Narrow	Shallow	27	1	No
125	IN	Carmel North	0.73	9,000	10	40	Flat	Clay	Cluster	Shallow	15	5	Yes
126	IN	Carmel South	1.30	12,000	0	40	Flat	Clay	Narrow	Shallow	10	8	Yes
127	MI	East Tawas	0.57	3,354	0	40	Flat	Sand	Nucleated	Shallow	50	7	No
131	MO	North Kansas City	3.50	6,950	90	37	Flat	Sand	Cluster	Deep	50	2	No
140	WI	Beloit	6.50	36,000	60	33	Moderate	Sand	Nucleated	Deep	25	11	No
145	CA	La Salina	3.25	22,500	0	12	Flat	Mixture	Cluster	Deep	49	13	No

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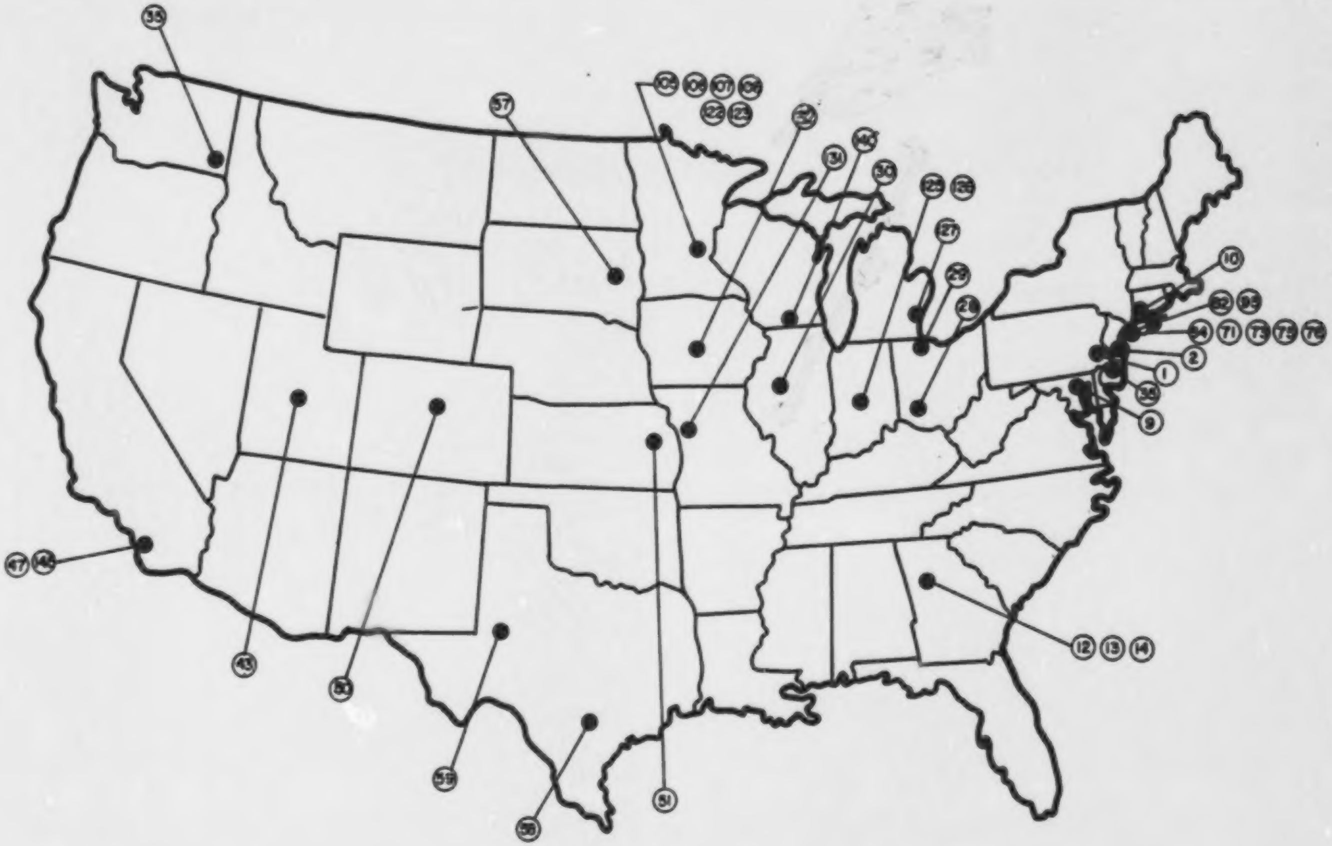

Figure 3. Location of selected POTW's.

Data Analysis and Approach

Data collected were analyzed in a series of steps designed to identify collection system parameters most influencing peak flows and to quantify those parameters as much as possible within the scope of this work. The influence of flow rate and sample time period on the peaking factor was also investigated. Finally, the special case of pump-dominated collection systems was examined.

Two independent approaches were used to identify significant collection system parameters and to quantify their impacts. They are termed collection system comparative assessments and data cluster analysis. The former assessment is summarized in Appendix A. The latter is found in Section 5, Results and Discussion. The other influences (flow rate, sample time, and pump-dominated systems) are discussed in Section 5. Pump-dominated systems data are also summarized in Appendix B.

Collection System Comparative Assessments --

This method involved a semi-qualitative/quantitative analysis and comparison of individual collection systems within common flow ranges. It was designed to reduce the importance of flow rate as a variable and to identify other collection system factors most influencial in affecting hourly diurnal flow variations. This was undertaken by:

1. Placing collection systems into categorized flow ranges.
2. Graphically displaying average diurnal flow variations as a function of the annual flow ratio (actual flow/annual average daily flow) in order to present the diurnal wave form for both spring and summer periods.
3. Identifying for each system the annual average hourly peaking factor defined as:

$$PF_A = \frac{\text{Average Peak } \frac{\text{Hour}}{\text{Day}} \text{ Per 10-Day Spring and 10-Day Summer Period}}{\text{Annual Average Flow}}$$

(i.e., one peaking factor for 10 days during the spring and one for 10 days during the summer), along with the variation of hourly data about the average peak hour of the day, presented as PF_A plus or minus two standard deviations ($\pm 2\sigma$).

4. Comparing two individual systems within a flow range and noting the dissimilar (not common to both) collection system parameters and their potential impact on wave forms, seasonal variations and peaking factors.

5. Isolating collection system parameters which were consistently identified with variations in the diurnal wave form, peaking factors, or seasonality, and making conclusions about the parameter impacts observed.

Data Cluster Analysis --

Utilizing information gained from the comparative assessment, collection systems containing parameters significantly affecting peak flows were compared to systems not containing these parameters. It was felt that combining or "clustering" peak flow data from the dissimilar systems would provide additional semi-quantitative information about the influence of the parameters most affecting peak flows. Comparison was made by plotting the average hourly peaking factor (PF_A) or maximum hourly peaking factor (PF_M) versus flow and noting the difference between dissimilar systems. Peaking factors were calculated as follows:

$$PF_A = \frac{\text{Average Peak } \frac{\text{Hour}}{\text{Day}} \text{ Per 10-Day Spring; 10-Day Summer; Total 20 Days}}{\text{Annual Average Daily Flow}}$$

$$PF_M = \frac{\text{Maximum Peak } \frac{\text{Hour}}{\text{Day}} \text{ Per 10-Day Spring; 10-Day Summer; Total 20 Days}}{\text{Annual Average Daily Flow}}$$

(i.e., average and maximum hourly peaking factors for 10 days during the spring, 10 days during the summer, and the combined 20 days of data).

Analysis of Other Influences --

The influence of flow rate was examined to determine its effect on the average hourly peaking factor by graphically displaying the calculated peaking factors as a function of the annual average collection system daily flow.

A year's data for one facility was compared to the spring plus summer 20-day data to assess relative differences between the seasonal data analyzed and the total annual data.

Influent flow to eight facilities was dominated by low lift pumping stations. As a result, the diurnal wave form did not reflect normal diurnal flow patterns, and these influent data were segregated from the remaining systems for independent analysis of their peaks.

SECTION 5

RESULTS AND DISCUSSION

COLLECTION SYSTEM PARAMETERS

Results of the Collection System Comparative Analysis are presented in detail in Appendix A. This includes a tabulated and graphical analysis of each collection system, highlighting observed peaking factors, the standard deviation of the data, the observed diurnal curve forms, and the preliminary conclusion associated with each individual comparative assessment. Additional discussions concerning this analysis are presented in Appendix A.

Table 4 lists average Hourly Peaking Factors (PF_A) and the Maximum Hourly Peaking Factors (PF_M) for each collection system for the total 20 days of data, 10 days during the spring, 10 days during the summer, and the peak hour of the day associated with each average value.

Differentiation of individual collection system parameters is an extremely difficult task. Each individual system contains numerous variables that exceeded the scope of this investigation insofar as quantitative identification is concerned. Nonetheless, three significant parameters stood out as dominant throughout the comparative analysis; these included industrial contributions, average age of the collection system, and depth to groundwater.

Industrial Contributions

Systems with industrial or institutional contributions greater than 40 percent of the total collection system flow (when compared to systems with less than 40 percent) exhibited:

- Higher maximum hourly peaking factors (PF_M) than non-industrial systems.

- Higher average hourly peaking factors (PF_A) than non-industrial systems.

TABLE 4. SUMMARY OF PEAKING FACTORS FOR 31 SELECTED POTW'S[1]

I.D. No.	Average Annual Flow (MGD)	PF_M Maximum Peak Hour/Day For 20 Days	PF_A Average Peak Hour/Day For 20 Days ± 2σ (Peak Hour)	PF_M Maximum Peak Hour/Day For 10 Days In Spring	PF_A Average Peak Hour/Day For 10 Days In Spring ± 2σ (Peak Hour)	PF_M Maximum Peak Hour/Day For 10 Days In Summer	PF_A Average Peak Hour/Day For 10 Days In Summer ± 2σ (Peak Hour)
9(2)	.07	4.39	1.30 ± 0.90 (20:00)	2.65	1.32 ± 1.10 (20:00)	4.39	1.57 ± 2.47 (12:00)
123	.24	1.90	0.97 ± 0.22 (10:00)	1.43	1.00 ± 0.42 (20:00)	1.90	0.97 ± 0.25 (12:00)
43	.35	2.00	1.24 ± 0.78 (10:00)	0.95	0.90 ± 0.20 (10:00)	2.00	1.65 ± 0.30 (12:00)
1	.36	1.44	1.13 ± 0.42 (11:00)	1.44	1.20 ± 0.25 (14:00)	1.27	1.15 ± 0.13 (11:00)
13	.42	1.75	1.30 ± 0.38 (22:00)	1.75	1.41 ± 0.57 (13:00)	1.34	1.15 ± 0.28 (22:00)
108	.42	1.60	1.28 ± 0.32 (12:00)	1.60	1.38 + 0.31 (12:00)	1.45	1.15 ± 0.17 (12:00)
106	.50	2.10	1.45 ± 0.43 (10:00)	2.10	1.50 ± 0.55 (10:00)	1.85	1.48 ± 0.29 (13:00)
127	.57	1.72	1.07 ± 0.64 (10:00)	1.72	1.30 ± 0.55 (10:00)	1.49	0.90 ± 0.46 (14:00)
125	.73	1.65	1.23 ± 0.41 (13:00)	1.51	1.15 ± 0.38 (12:00)	1.65	1.35 ± 0.35 (14:00)
82	.83	1.95	1.49 ± 0.39 (10:00)	1.44	1.42 ± 0.12 (10:00)	1.95	1.86 ± 0.17 (10:00)
122	.85	1.66	1.05 ± 0.52 (14:00)	1.66	1.45 ± 0.15 (19:00)	1.11	1.00 ± 0.14 (20.00)
126(2)	1.30	1.69	1.06 ± 0.71 (10:00)	1.69	1.40 ± 0.35 (09:00)	1.69	0.90 ± 0.39 (12:00)
12(3)	1.57	1.90	0.93 ± 0.32 (15:00)	1.90	0.90 ± 0.44 (11:00)	1.08	1.05 ± 0.12 (15:00)
64	1.59	2.82	1.35 ± 0.18 (12:00)	1.70	1.32 ± 0.20 (12:00)	2.82	1.45 ± 0.12 (11:00)
35(4)	1.60	3.00	1.27 ± 0.64 (14:00)	2.25	1.13 ± 0.71 (14:00)	3.00	1.48 ± 1.32 (18:00)
105	1.90	1.69	1.42 ± 0.24 (11:00)	1.69	1.45 ± 0.24 (20:00)	1.55	1.41 ± 0.17 (11:00)
50	2.50	2.00	1.22 ± 0.24 (11:00)	2.00	1.25 ± 0.43 (20:00)	1.52	1.25 ± 0.22 (13:00)
14(3)	2.69	1.63	1.12 ± 0.24 (12:00)	1.15	1.10 ± 0.05 (20:00)	1.63	1.19 ± 0.17 (13:00)
57(2)	2.70	2.75	1.30 ± 1.33 (12:00)	2.75	1.40 ± 1.50 (13:00)	2.65	1.18 ± 1.13 (12:00)
33	3.10	2.65	1.56 ± 1.29 (08:00)	2.65	2.17 ± 0.50 (08:00)	1.29	1.10 ± 0.21 (10:00)
145	3.25	1.90	1.46 ± 0.33 (11:00)	1.90	1.49 ± 0.17 (11:00)	1.65	1.45 ± 0.13 (11:00)
73(2)	4.20	2.19	1.27 ± 0.61 (20:00)	2.19	1.60 ± 0.48 (09:00)	1.42	1.15 ± 0.24 (12:00)
58(3)	5.00	1.27	1.01 ± 0.33 (15:00)	1.27	0.95 ± 0.39 (15:00)	1.24	1.10 ± 0.24 (15:00)
32	5.00	1.80	1.18 ± 0.38 (14:00)	1.80	1.38 ± 0.36 (12:00)	1.15	1.05 ± 0.11 (14:00)
51	5.00	1.94	1.34 ± 0.57 (12:00)	1.94	1.59 ± 0.27 (12:00)	1.30	1.08 ± 0.25 (12:00)
59	6.20	1.32	1.19 ± 0.13 (15:00)	1.32	1.16 ± 0.19 (15:00)	1.24	1.20 ± 0.04 (16:00)
10	7.30	1.63	1.20 ± 0.23 (13:00)	1.38	1.22 ± 0.20 (13:00)	1.63	1.19 ± 0.28 (13:00)
107	13	1.65	1.25 ± 0.31 (14:00)	1.60	1.29 ± 0.30 (14:00)	1.65	1.29 ± 0.31 (16:00)
30(4)	30	1.92	1.24 ± 0.85 (14:00)	1.92	1.62 ± 0.58 (15:00)	1.00	0.90 ± 0.09 (13:00)
71	64	1.25	1.13 ± 0.13 (12:00)	1.25	1.19 ± 0.08 (12:00)	1.15	1.08 ± 0.08 (20:00)
29(4)	78	2.32	1.32 ± 0.99 (14:00)	2.32	1.56 ± 1.15 (14:00)	1.51	1.12 ± 0.45 (16:00)

(1) Excluding 8 Pump Dominated Systems (I.D. Nos. 2, 28, 47, 75, 76, 95, 131,140)
(2) Inflow
(3) Equalization/Storage or Limiting Bypass
(4) Partially Combined Sewer System

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- Greater seasonal variations in average hourly peaking factors (PF_A) than non-industrial systems.

- Peak hours which differed from non-industrial systems.

Once it became apparent that industrial systems exhibited these variations, they were isolated from the remaining non-industrial systems for independent analysis. Tables 5 and 6 list the maximum (PF_M) and average hourly (PF_A) peaking factors for the industrial and non-industrial systems, respectively.

Figure 4 depicts the maximum hourly peaking factors observed for 20 days of industrial systems with contributions greater than 40 percent, compared to those systems with contributions less than 40 percent. The higher peaking factors associated with the industrial systems are noticeable and average approximately 1-2 times the maximum peak hours of non-industrial systems (individual industrial systems varying up to two times that of non-industrial systems).

Average hourly peaking factors (PF_A) for industrial systems, presented in Table 6, normally exceed those for non-industrial systems, averaging approximately 1.1 times those values observed in non-industrial systems.

Industries can be expected to exhibit seasonal variations in discharges resulting from periods of water-intensive activities. Figure 5 illustrates this seasonal variation of average hourly peaking factors. Of the seven industrial systems examined, four had greater variation during the spring, and three had greater variation during the summer (Table 7). Average hourly peaking factors (PF_A) for industrial systems during the high-flow industrial season normally exceeded those for non-industrial systems during the high-flow season (i.e., spring or summer). This is graphically presented in Figure 5 and tabulated in Table 7, which compares PF_A in peak-flow seasons for industrial and non-industrial systems.

Finally, systems where industrial contributions are greater than 40 percent influence the scheduled peak hour as a result of the individual industrial schedules. Table 8 lists the distribution of observed peak hours for the industrial and non-industrial systems. In the systems examined, industrial systems tended to generate peak flows earlier than those observed in non-industrial systems.

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TABLE 5. SUMMARY OF INDUSTRIAL AND NON-INDUSTRIAL MAXIMUM HOURLY PEAKING FACTORS (PF_M)

TOTAL 20 DAYS				SPRING 10 DAYS				SUMMER 10 Days			
PF_M 7 Industrial		PF_M 14 Non-Industrial		PF_M 7 Industrial		PF_M 14 Non-Industrial		PF_M 7 Industrial		PF_M 14 Non-Industrial	
I.D. No.	PF_M	I.D. No.	PF_M	I.D. No.	PF_M	I.D. No.	PF_M	I.D. No.	PF_M	I.D. No.	PF_M
123	1.90	1	1.44	123	1.43	1	1.44	123	1.90	1	1.27
143	2.00	13	1.75	143	.95	13	1.75	143	2.00	13	1.34
106	2.10	108	1.60	106	2.10	108	1.60	106	1.85	108	1.45
82	1.95	127	1.72	82	1.44	127	1.72	82	1.95	127	1.49
33	2.65	125	1.65	33	2.65	125	1.51	33	1.29	125	1.65
32	1.80	122	1.66	32	1.80	122	1.66	32	1.15	122	1.11
51	1.94	64	2.82	51	1.94	64	1.70	51	1.30	64	2.82
	$PF_{\bar{M}}$ = 2.05	105	1.69		$PF_{\bar{M}}$ = 1.76	105	1.69		$PF_{\bar{M}}$ = 1.63	105	1.55
		50	2.00			50	2.00			50	1.52
		145	1.90			145	1.90			145	1.65
		59	1.32			59	1.32			59	1.24
		10	1.38			10	1.38			10	1.63
		107	1.60			107	1.60			107	1.65
		71	1.25			71	1.25			71	1.15
			$PF_{\bar{M}}$ = 1.70				$PF_{\bar{M}}$ = 1.61				$PF_{\bar{M}}$ = 1.54

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TABLE 6. SUMMARY OF INDUSTRIAL AND NON-INDUSTRIAL AVERAGE HOURLY PEAKING FACTORS (PF_A)

TOTAL 20 DAYS							
PF_A 7 Industrial				PF_A 14 Non-Industrial			
I.D. No.	$\bar{X}$	σ	$\sigma/\bar{X}$	I.D. No.	$\bar{X}$	σ	$\sigma/\bar{X}$
123	.97	.11	.11	1	1.13	.21	.19
43	1.24	.39	.32	13	1.30	.19	.15
106	1.45	.22	.15	108	1.28	.16	.14
82	1.49	.20	.13	127	1.07	.32	.30
33	1.56	.64	.41	125	1.23	.20	.16
32	1.18	.16	.14	122	1.05	.26	.25
51	1.34	.28	.21	64	1.35	.09	.07
$PF_{\bar{A}}$ =	1.32			105	1.42	.12	.09
				50	1.22	.12	.10
				145	1.46	.16	.11
				59	1.19	.07	.06
				10	1.20	.12	.10
				107	1.25	.16	.13
				71	1.13	.07	.06
				$PF_{\bar{A}}$ =	1.23		

SPRING 10 DAYS							
PF_A 7 Industrial				PF_A 14 Non-Industrial			
I.D. No.	$\bar{X}$	σ	σ/X	I.D. No.	$\bar{X}$	σ	$\sigma/\bar{X}$
123	1.00	.21	.21	1	1.20	.12	.10
43	.90	.10	.11	13	1.41	.28	.20
106	1.50	.28	.19	108	1.38	.15	.11
82	1.42	.06	.04	127	1.30	.27	.21
33	2.17	.25	.12	125	1.15	.19	.17
32	1.38	.18	.13	122	1.45	.07	.05
51	1.59	.14	.09	64	1.32	.10	.08
$PF_{\bar{A}}$	1.42			105	1.45	.12	.08
				50	1.25	.21	.17
				145	1.49	.08	.05
				59	1.16	.09	.08
				10	1.22	.10	.08
				107	1.29	.15	.12
				71	1.19	.04	.03
				$PF_{\bar{A}}$ =	1.30		

SUMMER 10 DAYS							
PF_A 7 Industrial				PF_A 14 Non-Industrial			
I.D. No.	$\bar{X}$	σ	$\sigma/\bar{X}$	I.D. No.	$\bar{X}$	σ	$\sigma/\bar{X}$
123	0.97	.13	.09	1	1.15	.06	.05
43	1.65	.15	.09	13	1.15	.14	.12
106	1.48	..15	.10	108	1.15	.08	.07
82	1.86	.09	.05	127	0.90	.23	.26
33	1.10	.12	.11	125	1.35	.18	.13
32	1.05	.06	.06	122	1.00	.07	.07
51	1.08	.12	.11	64	1.45	.06	.04
$PF_{\bar{A}}$	1.30			105	1.41	.08	.06
				50	1.25	.11	.09
				145	1.45	.06	.04
				59	1.20	.02	.02
				10	1.19	.14	.12
				107	1.29	.15	.12
				71	1.08	.04	.04
				$PF_{\bar{A}}$ =	1.22		

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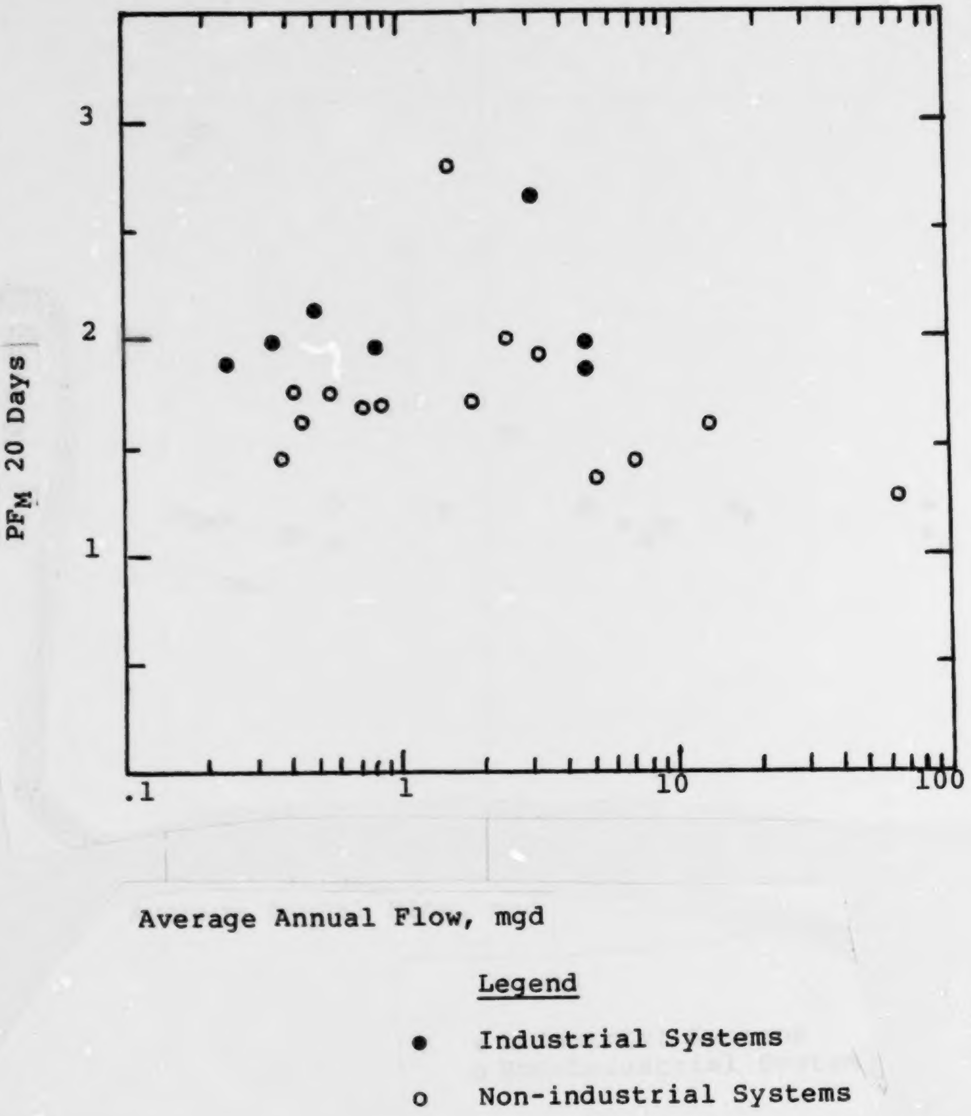

Figure 4 Industrial and non-industrial maximum hourly peaking factors.

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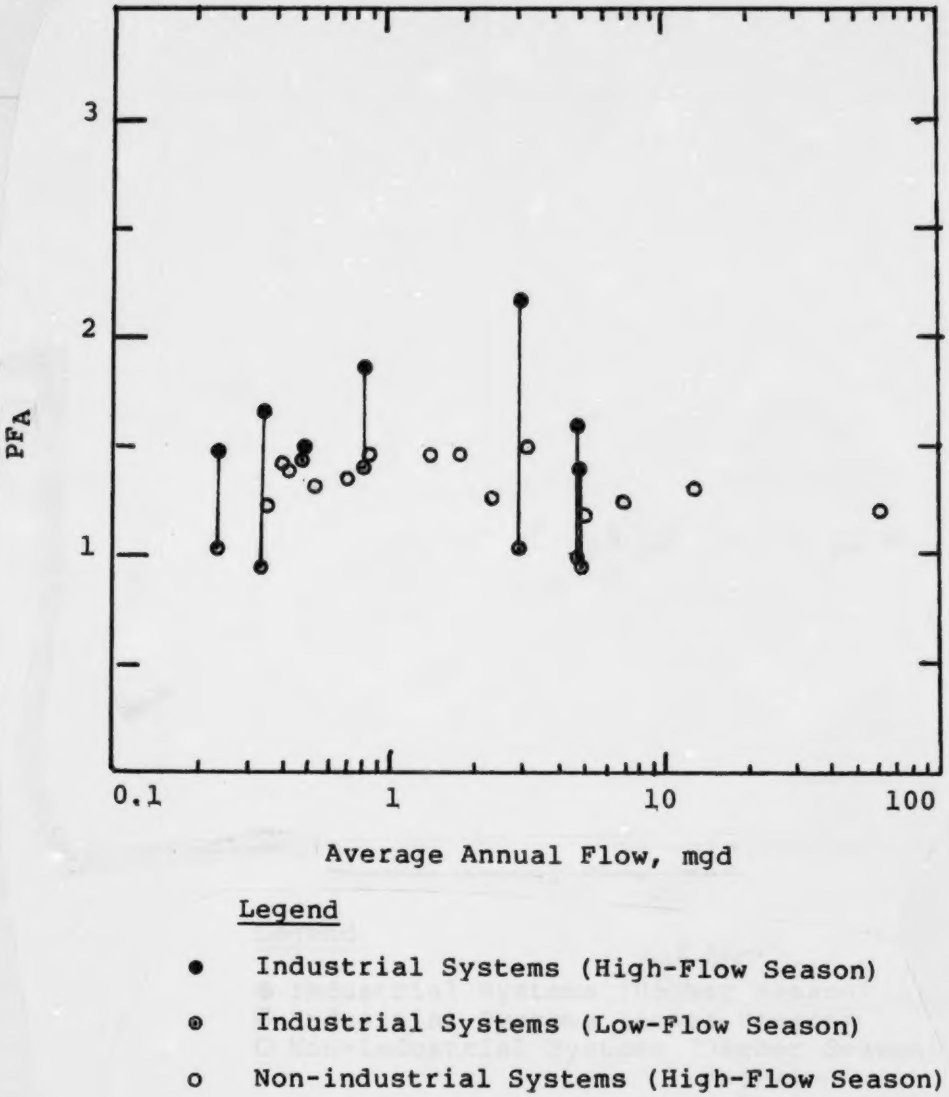

Figure 5. Industrial and non-industrial season average daily peaking factors.

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TABLE 7. SUMMARY OF INDUSTRIAL AND NON-INDUSTRIAL AVERAGE HOURLY PEAKING FACTOR (PF_A) FOR HIGH-FLOW SEASON(1)

7 INDUSTRIAL			14 NON-INDUSTRIAL		
I.D. No.	High-Flow Season	PF_A	I.D. No.	High-Flow Season	PF_A
123	Summer	1.00(2)	1	Spring	1.20
43	Summer	1.65	13	Spring	1.41
106	Spring	1.50	108	Spring	1.38
82	Summer	1.86	127	Spring	1.30
33	Spring	2.17	125	Summer	1.35
32	Spring	1.38	122	Spring	1.45
51	Spring	1.57	64	Summer	1.45
		$PF_{\bar{A}} = 1.59$	105	Spring	1.45
			50	Summer & Spring	1.25
			145	Spring	1.49
			59	Summer	1.20
			10	Spring	1.22
			107	Summer & Spring	1.29
			71	Spring	1.19
					$PF_{\bar{A}} = 1.33$

---

(1) The season is either 10 days in spring or 10 days in summer.
(2) Low value due to no industrial flow in flow records examined.

TABLE 8. DISTRIBUTION OF PEAK HOURS

	INDUSTRIAL SYSTEMS			NON-INDUSTRIAL SYSTEMS		
Time (Hours)	Total(1)	Spring(2)	Summer(3)	Total(1)	Spring(2)	Summer(3)
0800 - 1000	1	1	0	0	2	0
1000 - 1200	4	3	2	6	3	4
1200 - 1400	1	2	4	7	7	9
1400 - 1600	1	0	1	8	7	4
1600 - 1800	0	0	0	0	0	3
1800 - 2000	0	0	0	0	1	1
2000 - 2200	0	1	0	2	4	2
2200 - 2400	0	0	0	1	0	1

---

(1) Represents 20 days sample population period
(2) Represents 10 days in spring sample population period
(3) Represents 10 days in summer sample population period

Average Age and Groundwater Elevation

Collection systems which were old (> 25 years average age) and experienced high groundwater exhibited marked seasonal (spring to summer) variations in observed peaking factors. This marked variation was not apparent in systems that did not have these characteristics.

Figure 6 compares the seasonal variation in average hourly peaking factors of old sanitary sewer collection systems experiencing high groundwater with other systems. Unlike other systems, old systems having high groundwater exhibit spring peaking factors 1.1 to 1.5 times those observed in the summer. This results from greater susceptibility to infiltration during the spring season and increases both the flow and the Annual Peaking Factor.

PEAKING FACTOR MAGNITUDES

Table 9 presents the mean of all average hourly peaking factors (PF_A) and maximum hourly peaking factors (PF_M) for both spring and summer and total 20 days of data. These mean values are derived from the data presented in Tables 5 and 6.

For non-industrial systems, the mean of all average hourly peaking factors was 1.23, 1.30, and 1.22 for the total 20 days, spring and summer values, respectively.

The maximum hourly peaking factor mean observed was 1.70, 1.61, and 1.54 for the total 20 days, spring and summer values, respectively. The greater the number of days included in the sample time period, the greater the maximum hourly peaking factor possible.

Examination of mean values for industrial systems with flow contributions greater than 40 percent reflect the higher average peaks exhibited by most industrial systems as illustrated by the 1.32, 1.42, and 1.30 average hourly peaking factors for the total 20 days, spring and summer periods, respectively. Table 7 also lists a mean value of 1.59 for peak industrial seasons, where increases in industrial activity increased the peak flows observed.

Maximum hourly peaking factor means for industrial systems were 2.05, 1.76, and 1.63 for the total 20 days, spring and summer time periods, respectively.

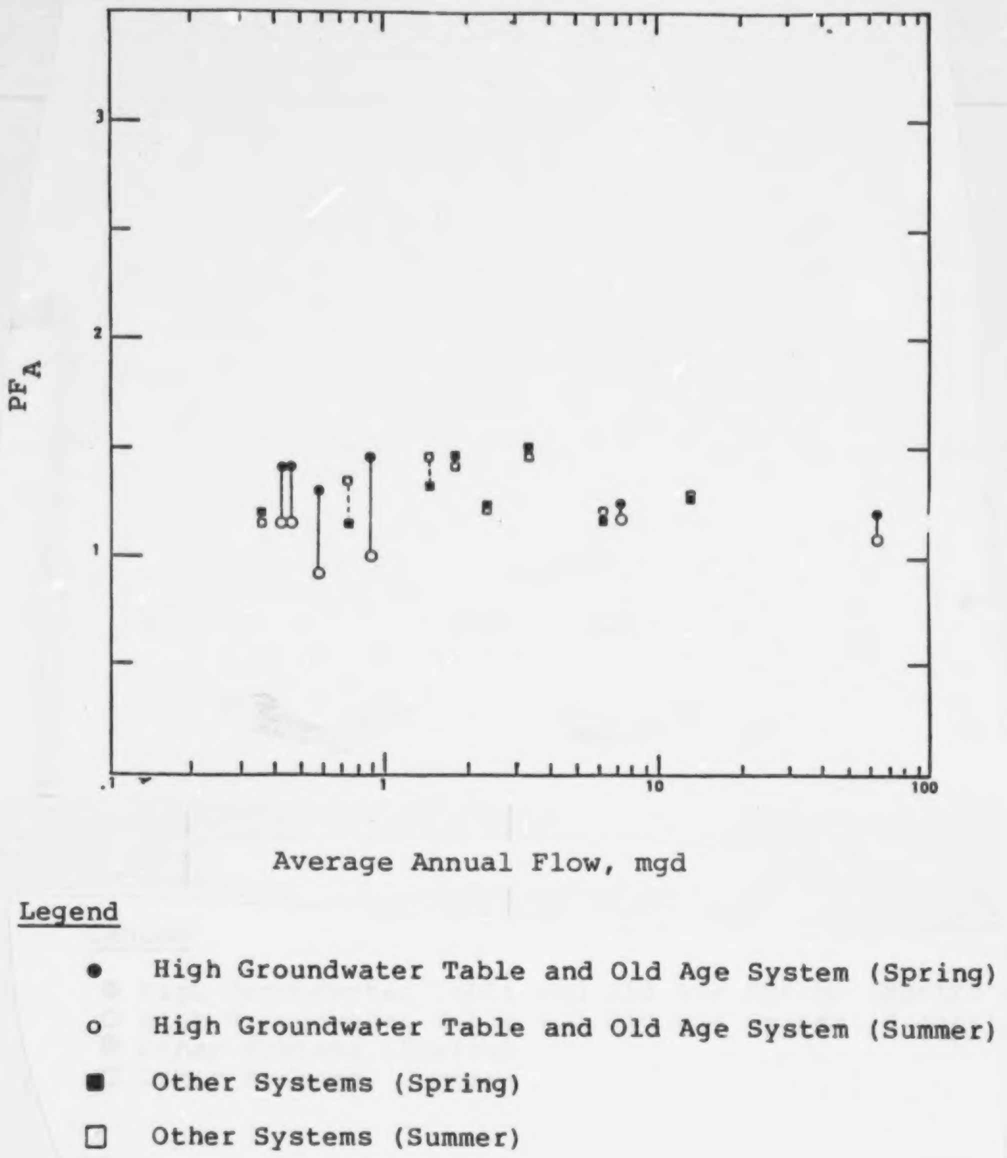

Figure 6 Seasonal variations of peaking factors (PF_A) of high groundwater table and old age systems versus other systems.

TABLE 9. MEAN AVERAGE HOURLY AND MAXIMUM HOURLY PEAKING FACTORS*

I. 14 NON-INDUSTRIAL SYSTEMS

$PF_{\bar{A}}$ = 1.23 for 20 days

$PF_{\bar{A}}$ = 1.30 for 10 days in spring

$PF_{\bar{A}}$ = 1.22 for 10 days in summer

II. 14 NON-INDUSTRIAL SYSTEMS

$PF_{\bar{M}}$ = 1.70 for 20 days

$PF_{\bar{M}}$ = 1.61 for 10 days in spring

$PF_{\bar{M}}$ = 1.54 for 10 days in summer

III. 7 INDUSTRIAL SYSTEMS

$PF_{\bar{A}}$ = 1.32 for 20 days

$PF_{\bar{A}}$ = 1.42 for 10 days in spring

$PF_{\bar{A}}$ = 1.30 for 10 days in summer

$PF_{\bar{A}}$ =1.59 for industrial season
(either 10 days in spring or 10 days in summer)

IV. 7 INDUSTRIAL SYSYEMS

$PF_{\bar{M}}$ = 2.05 for 20 days

$PF_{\bar{M}}$ = 1.76 for 10 days in spring

$PF_{\bar{M}}$ = 1.63 for 10 days in summer

NOTE: the mean peaking factors summarized in this table are calculated independently from sample data taken during the applicable time period. Thus 20 day mean peaking factor numbers cannot be calculated simply by noting the 10 day spring and summer mean peaking factor numbers shown here. Section 4 of the report elaborates on the statistical approach used to calculate these peaking factors.

FLOW RATE AND PEAKING FACTORS

Within the range of values tested, the average hourly peaking factors for non-industrial systems did not vary significantly with flow rates, maintaining a mean value of approximately 1.23 (Figure 7).

Maximum hourly peaking factor values exhibited some slight decrease (Figure 4) in peaking factors with flow; however, the outlying values produced poor correlation with any attempted flow/peaking factor relationship.

As flow increased, however, the standard deviation or fluctuation around the average peak hour per day decreased. Figure 8 presents a log plot of the coefficient of variation vs. flow for average hourly peaking factors (PF_A). The coefficient of variation is defined as the standard deviation divided by the average value ($\sigma/\bar{x}$) and is generally expressed as a percentage. Values for $\sigma/\bar{x}$ are presented for each average hourly peaking factor in Table 6. Figure 8 depicts this decreasing trend with increasing flow rate, which is highlighted by the negatively-sloped line drawn through the data. This implies that greater flow variation around the mean value can be expected in lower flow ranges, while smaller flow variations are expected in higher flow ranges.

ANNUAL TIME PERIOD VS. SAMPLE TIME PERIOD

Annual flow data for one facility at Ames, Iowa (I.D. No. 32) was collected and analyzed for one year, 10 days during spring, and 10 days during summer time periods. Figure 9 graphically depicts the average diurnal variation and the maximum and minimum hourly value observed for the total year, the spring and the summer data, respectively. Some shifting in the peak hour exists among the time periods. The annual, spring, and summer peak hour occurred approximately 1500, 1300, and 1400 hours, respectively.

Peaking summaries of Figure 9 graphical data are presented in Table 10. The average hourly and the maximum hourly peaking factor for the annual time period was 1.35 and 2.70, respectively. For the spring period, these values were 1.38 and 1.80, respectively; for the summer periods, these values were 1.05 and 1.15, respectively. For the 20-day sample time period, these values were 1.18 and 1.80, respectively.

Maximum hourly peaking factors increase as the time period increases. Data from limited time periods (i.e., spring or summer) do not represent the annual time period. It must be noted

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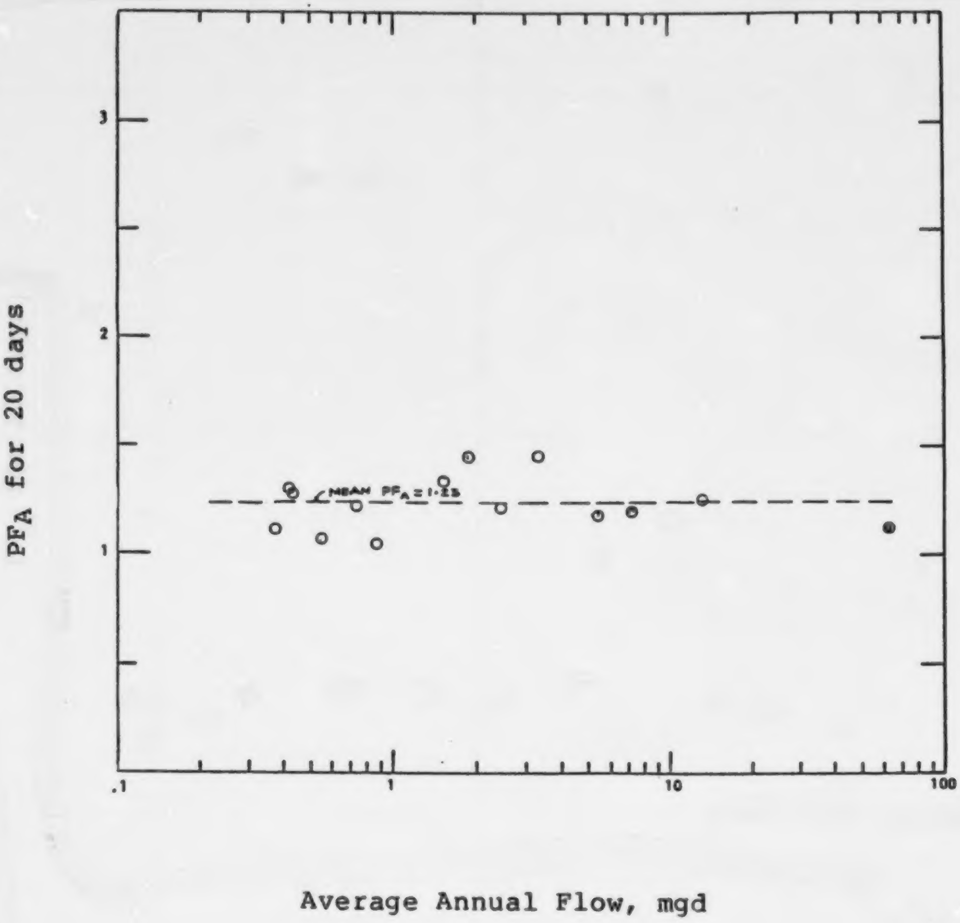

Figure 7. Non-industrial average hourly peaking factors.

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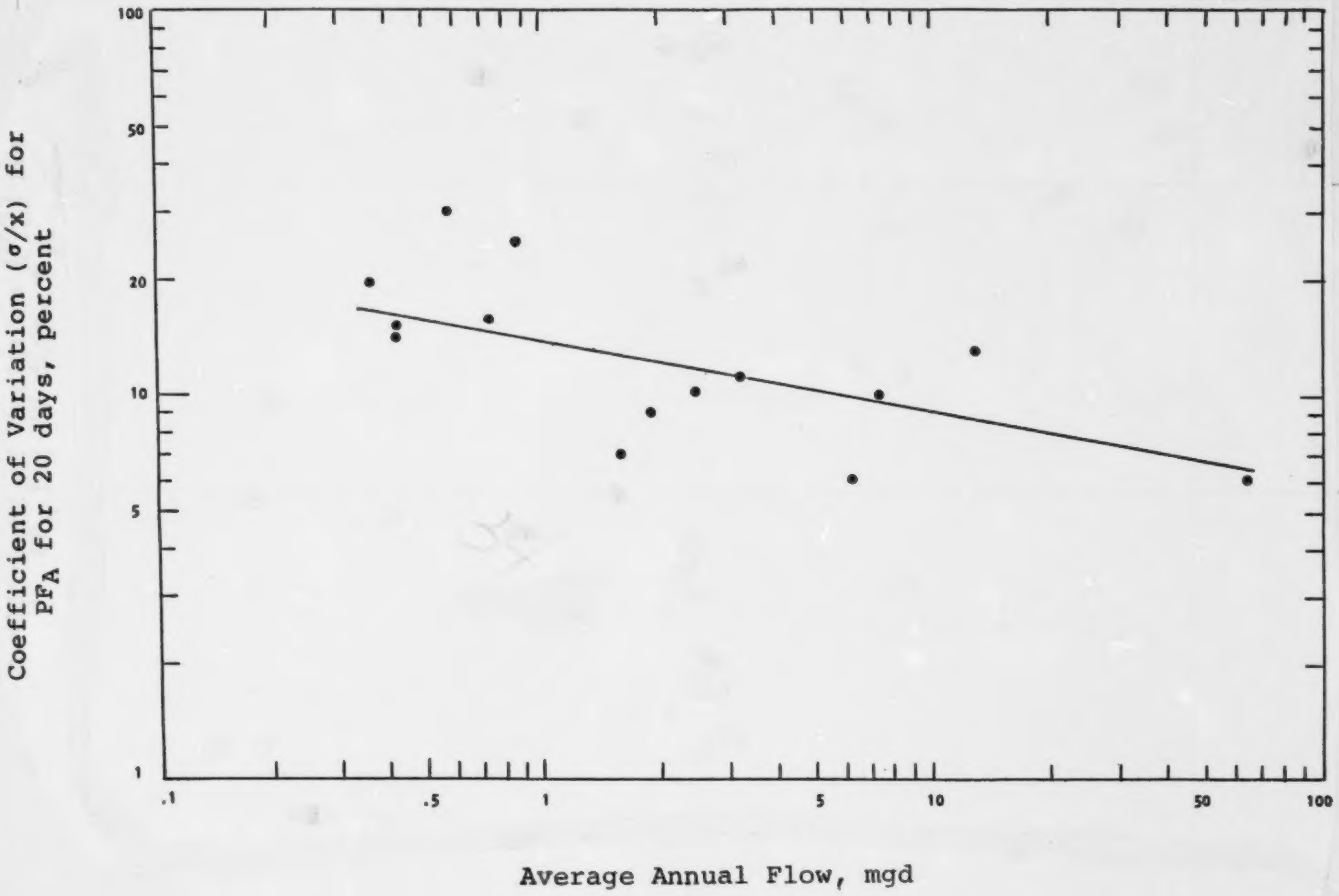

Figure 8. Variation of average hourly peaking factor distribution .

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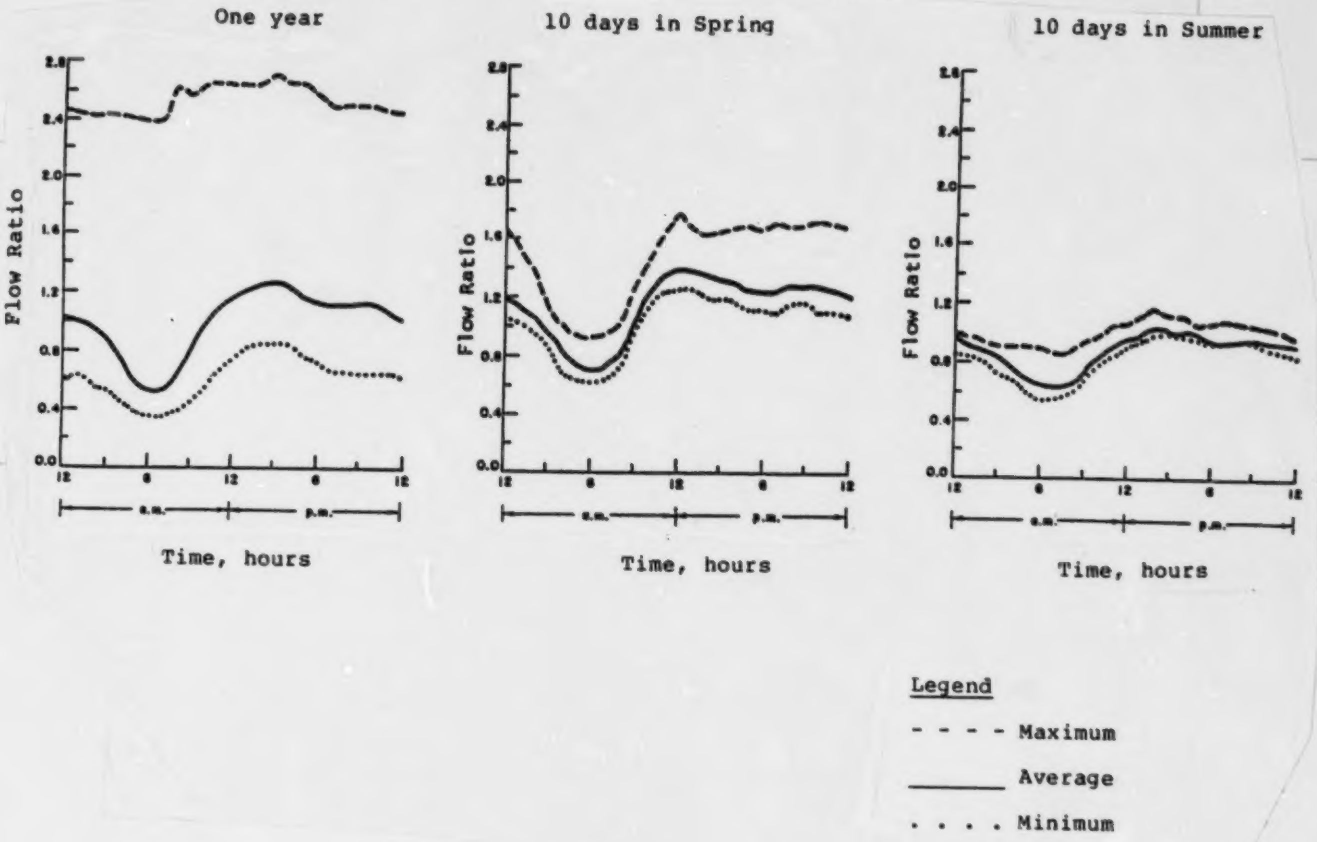

Figure 9. Diurnal hydraulic variation relationship between one year, spring, and summer. (The average annual flow at Ames, Iowa is 5.0 mgd.)

TABLE 10. PEAKING FACTORS FOR ANNUAL PERIOD AND SAMPLE TIME PERIODS AT AMES, IOWA

Time Period	PF_A	PF_M
Annual	1.35	2.70
Spring (10 days)	1.38	1.80
Summer (10 days)	1.05	1.15
Total 20 Days	1.18	1.80

that the annual flow ratio includes potential inflow which was not eliminated when examining this data. The result is that the maximum observed events will be greater. The average analysis over the year tends to reduce the severity of inflow.

The average hourly peaking factor for the annual period of 1.35 was very close to the 1.38 observed during the spring period. The summer period's low value of 1.05 was the result of a decreasing population and flow rate during the summer in the collection system. The Ames, Iowa sanitary sewer system was classified as an industrial system due to the high institutional flow which decreased during the summer months. The annual value (PF_A) of 1.35 was slightly higher than the mean value of 1.32 for the industrial collection systems previously examined (Table 9).

PUMP-DOMINATED SYSTEMS

Many sewage treatment plants contain low lift pumping stations. Depending upon the design of the pumping station, diurnal variations and peaking at a facility can be controlled by this pumping station. The pumping station can minimize or eliminate the collection system as a factor. Eight facilities surveyed fell into this particular category (I.D. No. 2, 28, 47, 75, 76, 95, 131, 140).

Sample diurnal variations for these facilities are presented in Appendix B. Flow ratios are presented in Table 11. Maximum instantaneous flow ratios (peaking factors) varied from 1.3 to as much as 4.7. The frequency of pulses or number of peaks per hour ranged from 1 to 17 pulses per hour. Minimum instantaneous flow ratios ranged from 0 to 0.8.

It is apparent that low lift pumping stations designed to provide the required head and capacity without consideration of peaking effects can be the dominant factor influencing peak-flow magnitudes.

TABLE 11. FLOW VARIATIONS IN PUMP DOMINATED SYSTEMS

I.D. No.	Ratio of Maximum Actual Flow to Average Flow	Number of Peaks Per Hour	Ratio of Minimum Actual Flow to Average Flow
28	1.4	1-5	0.1
47	1.3	11	0.0
2	3.8	3-5	0.0
75	1.6	13-17	0.6
76	4.7	3-4	0.3
95	2.2	2-3	0.8
131	2.5	5-8	0.0
140	1.6	13-14	0.4

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APPENDIX A

COLLECTION SYSTEM COMPARATIVE ASSESSMENTS

INTRODUCTION

Appendix A contains the analysis of individual collection systems. Table A-1 groups them according to flow. Collection systems below 0.5 mgd are described and analyzed beginning in Table A-2. Collection systems for flows of 0.5-1.0, 1.0-5.0, 5.0-10.0, and greater than 10.0 mgd are described and analyzed in Tables A-3 through Table A-6, respectively. Individual comparative assessments are presented in outline format followed by a graphical representation of average hourly diurnal flow. The outline format is as follows:

I. DIURNAL HYDRAULIC VARIATION CURVE

- Peaking Factor ± 2 Standard Deviations for Spring and for Summer

---

Values for the average hourly peaking factors (PF_A) ± two standard deviations for the peak hourly value are presented for 10 days in the spring and 10 days in the summer.

- Wave Form

The diurnal wave form presented in each graphic was qualitatively defined for both spring and summer seasons according to the following definitions:

Typical: Represents a wave form that rises during early morning hours, peaking between 1000 and 1600 hours, and begins to fall between 2200 and 2400 hours until the early morning hours to complete a 24-hour cycle period. The flow variations from the minimum to maximum values of this cycle exhibit ± 40 percent to 70 percent of the average annual flow.

Sharp: Represents a wave form where the flow ratio between the minimum

	and maximum exceeds 70 percent of the average annual flow.
Flat:	Represents a wave form where the flow ratio between the minimum and maximum points of the wave form is less than 40 percent of the average annual flow.
Multi-Peak:	Represents a wave form having more than two noticeable pulses.

- Seasonal Variation

Seasonal variations (spring and summer) depicted in the diurnal wave form were defined as "yes" where a notable gap between spring and summer wave was formed, and "no" where this gap was not apparent.

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

- Dissimilar Collection System Parameters

Dissimilar collection system parameters for the system being compared were identified.

- Impacts of dissimilar collection parameters were described as "Yes" or "None". "Yes" referred to observed results which were consistent with anticipated results. For example, collection systems with high groundwater tables that periodically inundate the collection system would be expected to exhibit higher peaking than systems with deep groundwater tables. If this was observed, then the impact "Yes" was noted. If the expected result was not observed, then the impact "None" was noted. This qualitative method of analysis was used to isolate those parameters which consistently produced notable peaking trends.

- Description

The nature of the observed impact was described under this heading.

III. CONCLUSION

The preliminary conclusion concerning the analysis of the two systems investigated was presented.

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TABLE A-1. POTW's GROUPED BY FLOW

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Flow (mgd)	Name	State	I.D. No.
Below .5	Richlyn Manor	MD	9
	Lower Salford	PA	1
	Honey Creek	GA	13
	Salina STP	UT	43
	Salvage	MN	108
	Maple Plain	MN	123
.5 - 1	Hightstown	NJ	2
	West Long Beach	NY	76
	Kings Park #6	NY	82
	Bayport	MN	106
	Chaska	MN	122
	Carmel North	IN	125
	East Tawas	MI	127
1 - 5	Pole Bridge	GA	12
	Shoel Creek	GA	14
	Lebanon	OH	28
	Pullman	WA	33
	Gloucester	NJ	35
	San Luis Rey	CA	47
	Broomfield	CO	50
	Watertown	SD	57
	Belgrave	NY	64
	Freeport	NY	73
	Huntington	NY	95
	Anoke	MN	105
	Carmel South	IN	126
	North Kansas City	MO	131
	La Salina	CA	145
5 - 10	City of West Haven	CN	10
	Ames	IA	32
	Lawrence	KS	51
	Guadalupe	TX	58
	Midland	TX	59
	Long Beach	NY	75
	Beloit	WI	140
Above 10	Toledo	OH	29
	Greater Peoria	IL	30
	Bay Park	NY	71
	Blue Lake	MN	107

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TABLE A-2. POTW's AND COLLECTION SYSTEM PARAMETERS
FLOW RANGE: BELOW 0,5 MGD

I.D. No.	State	Name	Avg. Annual Flow (Mgd)	Popula-tion	Percent Indust. Contrib.	Avg. Annual Rainfall (In.)	Topography	Soil Type	Shape	Ground water Table	Avg. Age (Yrs.)	No. of Pump-ing Sta-tions	By-Pass
9	MD	Richlyn Manor	0.07	1,000	0	44	Rolling	Clay	Narrow	Shallow	18	1	No
1	PA	Lower Salford	0.36	4,500	21	40	Flat	Clay	Nucleated	Deep	15	2	Yes
13	GA	Honey Creek	0.42	5,000	10	48	Steep	Clay	Narrow	Shallow	45	2	No
43	UT	Salina STP	0.35	2,200	50	8	Steep	Clay	Cluster	Deep	20	0	No
108	MN	Salvage	0.42	3,000	27	27	Steep	Clay	Narrow	Shallow	40	3	No
123	MN	Maple Plain	0.24	1,400	50	27	Rolling	Clay	Narrow	Shallow	27	1	No

COMPARATIVE ASSESSMENT FOR LOWER SALFORD, PA. AND HONEY CREEK, GA.

I. DIURNAL HYDRAULIC VARIATION CURVE

	Lower Salford, PA	Honey Creek, GA
Peaking Factor		
PF_A (±2σ) - Spring	1.20 (±0.25)	1.40 (±0.57)
- Summer	1.15 (±0.13)	1.15 (±0.28)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	No	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Topography	None	
Groundwater Table	Yes	Honey Creek has high groundwater table and exhibits the seasonality.
Average Age	Yes	The older Honey Creek system (45 years) shows seasonal variation attributed to infiltration.
Bypass	None	

III. CONCLUSION

- Age and groundwater table were judged to be the predominant factors affecting seasonality.

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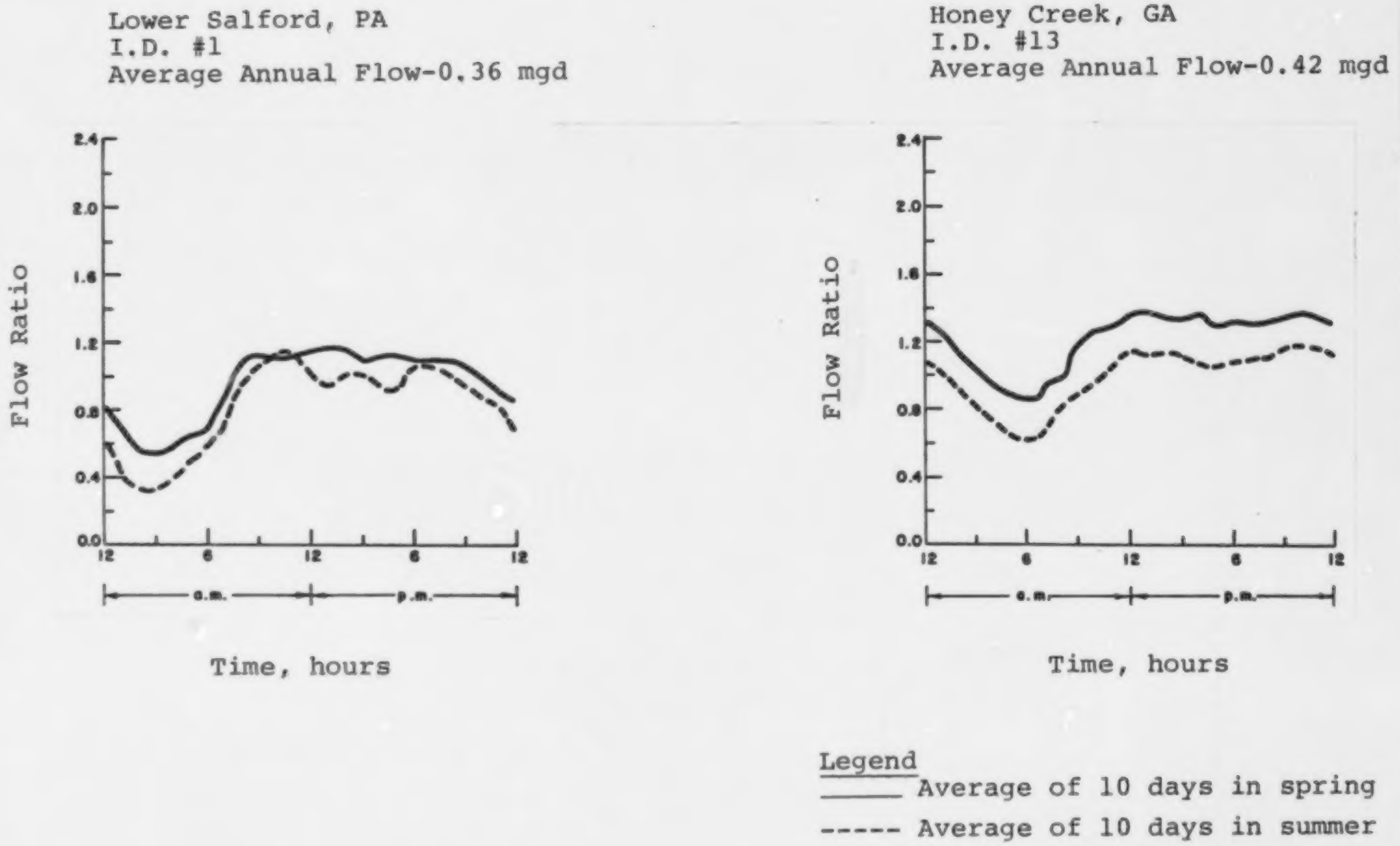

Lower Salford, PA
I.D. #1
Average Annual Flow-0.36 mgd

Honey Creek, GA
I.D. #13
Average Annual Flow-0.42 mgd

Legend
_____ Average of 10 days in spring
----- Average of 10 days in summer

Figure A-1. Diurnal hydraulic variation for I.D. #1 and #13.

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COMPARATIVE ASSESSMENT FOR HONEY CREEK, PA AND SALVAGE, MN

I. DIURNAL HYDRAULIC VARIATION CURVE

	Honey Creek	Salvage, MN
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.40 (±0.57)	1.38 (±0.31)
- Summer	1.15 (±0.28)	1.15 (±0.17)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	Yes	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimiliar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--

III. CONCLUSION

- Average annual rainfall is not a significant factor in this case.
- Similar collection systems result in indistinguishable curves.
- Although soil type for both systems are impervious clay, they both experience seasonality. This implies that the more dominant factors of seasonal variation is the high groundwater table and the age of the system.

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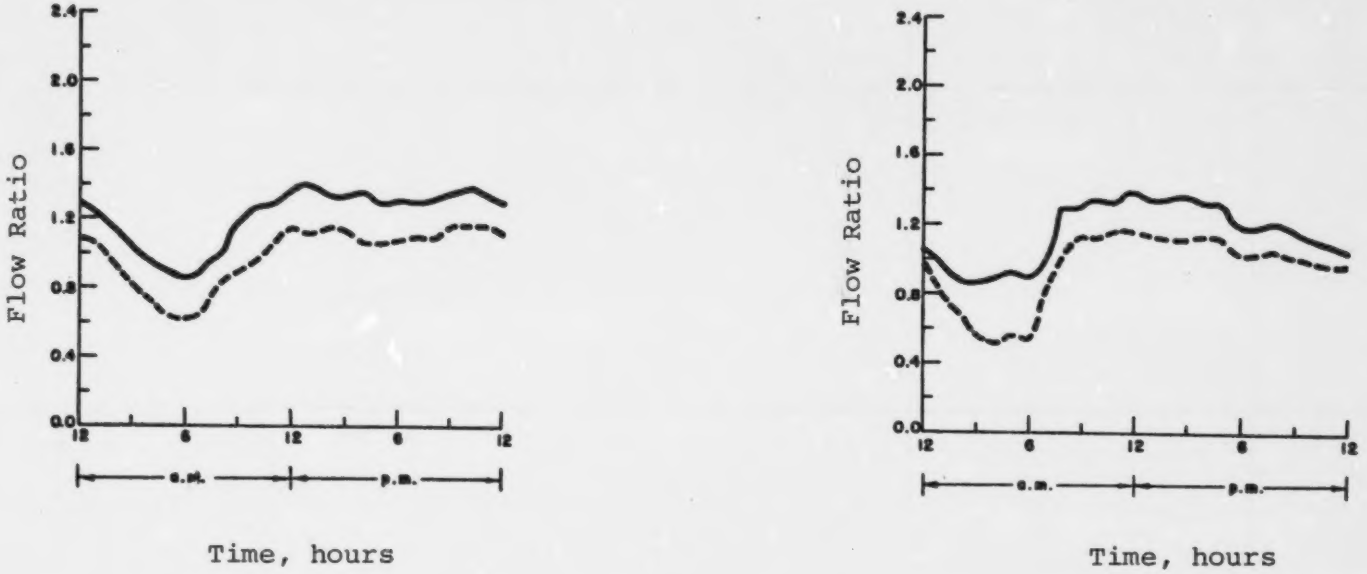

Honey Creek, GA
I.D. #13
Average Annual Flow - 0.42 MGD

Salvage, MN
I.D. #108
Average Annual Flow - 0.48 MGD

Legend

——— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-2. Diurnal hydraulic variation for I.D. #13 and #108.

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COMPARATIVE ASSESSMENT FOR SALVAGE, MN AND LOWER SALFORD, PA

I. DIURNAL HYDRAULIC VARIATION CURVE

	Salvage, MN	Lower Salford, PA
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.38 (±0.31)	1.20 (±0.25)
- Summer	1.15 (±0.17)	1.15 (±0.13)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	Yes	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Groundwater Table	Yes	Salvage has high groundwater and exhibits seasonality.
Average Age	Yes	Salvage is an old system and exhibits infiltration and seasonality.
Bypass	None	--

III. CONCLUSION

- Average annual rainfall is not a significant factor.
- An old system with high groundwater table exhibits seasonality.

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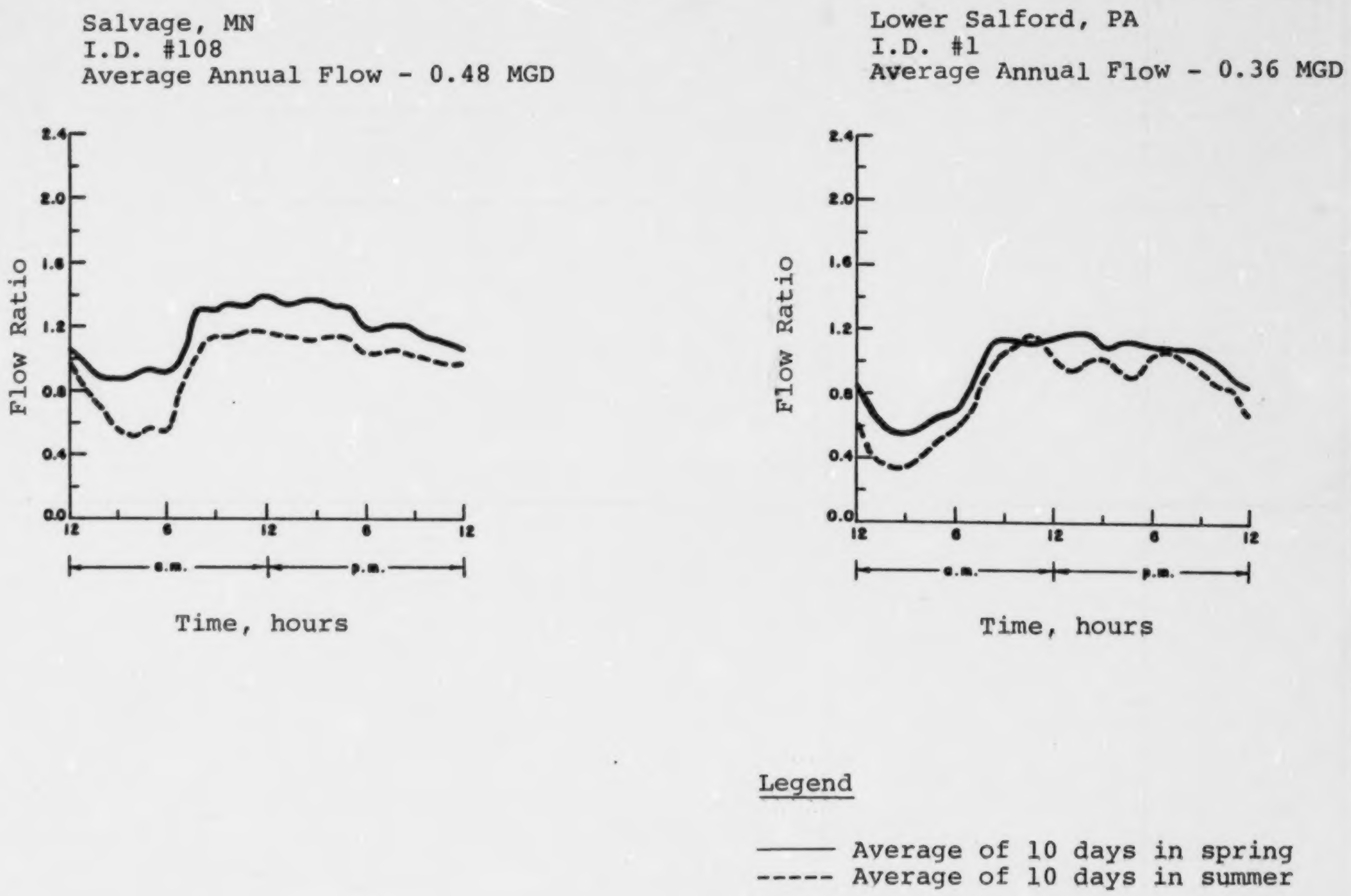

Figure A-3. Diurnal hydraulic variation for I.D. #108 and #1.

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COMPARATIVE ASSESSMENT FOR MAPLE PLAIN, MN AND SALVAGE, MN

I. DIURNAL HYDRAULIC VARIATION CURVE

	Maple Plain	Salvage
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.01 (±0.42)	1.40 (±0.31)
- Summer	0.97 (±0.25)	1.15 (±0.17)
Wave Form - Spring	Sharp and Multi-Peak	Typical
- Summer	Typical	Typical
Seasonal Variation	No	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Percent Industrial Contribution	Yes	Maple Plain plant has approximately 50% industrial flow and 60% of the industrial flow is contributed by cooling water which is discharged continuously between 8:00 a.m. and 9:00 p.m.; exhibits the sharp and multi-peak wave form in spring during that period.
Topography	None	--
Average Age	Yes	Salvage is 40 years old and shows seasonality and infiltration.

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III. CONCLUSION

- An industry dominated system can exhibit a sharp and multi-peak wave form.
- An older system shows seasonal variation.
- The old age and high groundwater table system exhibits seasonal variation (infiltration) while a young age and high groundwater table system did not.
- The Maple Plain curve shows a low peaking factor of about 1.0. This low value could have resulted from flow records obtained during the low industrial season or an incorrect annual average daily flow.

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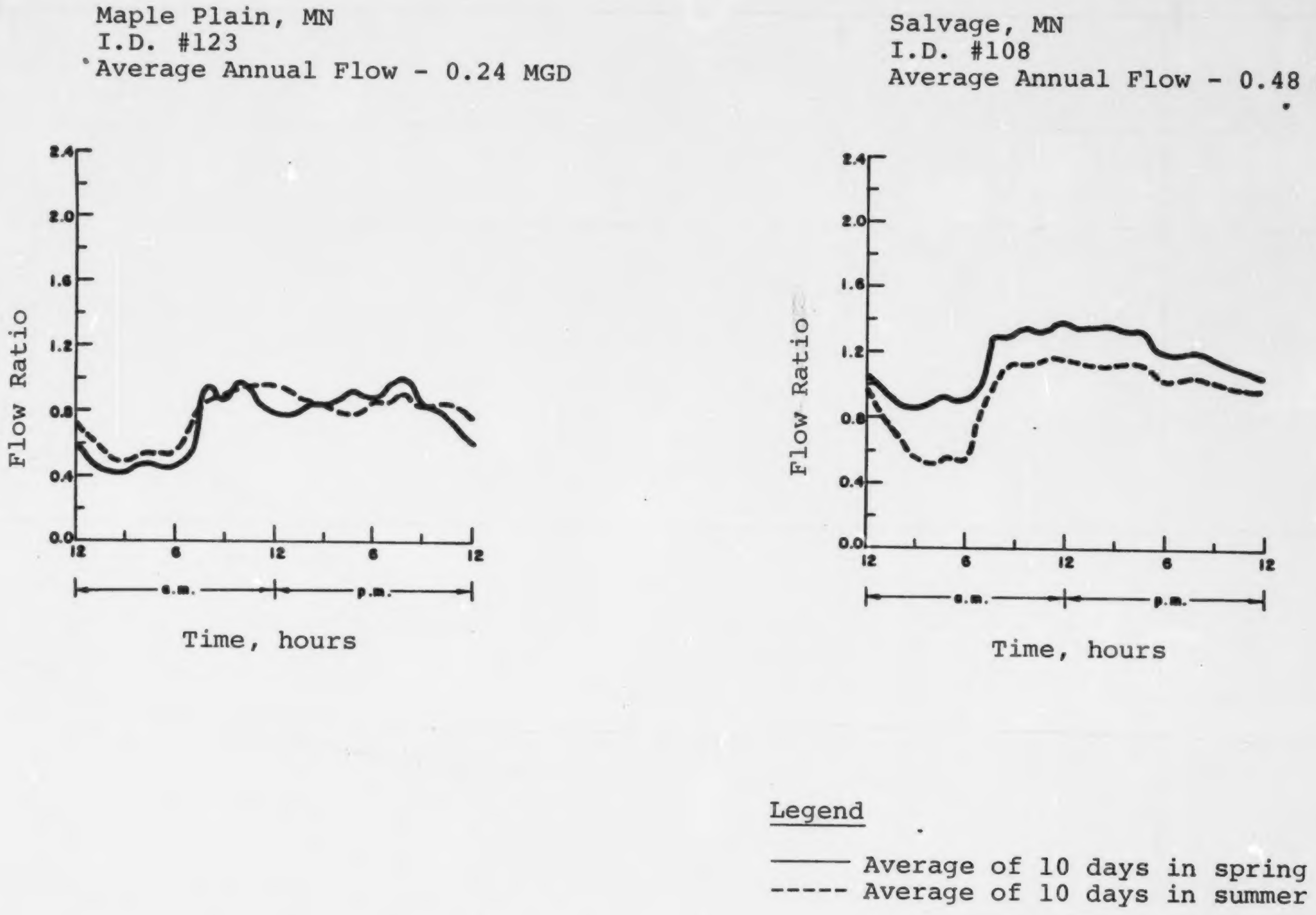

Maple Plain, MN
I.D. #123
Average Annual Flow - 0.24 MGD

Salvage, MN
I.D. #108
Average Annual Flow - 0.48 MGD

Figure A-4. Diurnal hydraulic variation for I.D. #123 and #108.

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COMPARATIVE ASSESSMENT FOR SALINA, UT AND LOWER SALFORD, PA

I. DIURNAL HYDRAULIC VARIATION CURVE

	Salina	Lower Salford
Peaking Factor PF_A ($\pm 2\sigma$) - Spring	0.90 (±0.20)	1.20 (±0.25)
- Summer	1.65 (±0.30)	1.15 (±0.13)
Wave Form - Spring	Typical	Typical
- Summer	Sharp	Typical
Seasonal Variation	Yes	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Percent Industrial Contribution	Yes	Salina has 50 percent flow from a seasonal poultry industry which accounts for the sharp wave form in summer and marked seasonal variation.
Annual Average Rainfall	None	--
Topography	None	--
Shape	None	--
Number of Pumping Stations	None	--
Bypass	None	--

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III. CONCLUSION

- A system that has significant industrial contribution (in this case 50%) can exhibit a sharp wave form with seasonal variation.
- This industrial contribution can mask all other collection system parameters.

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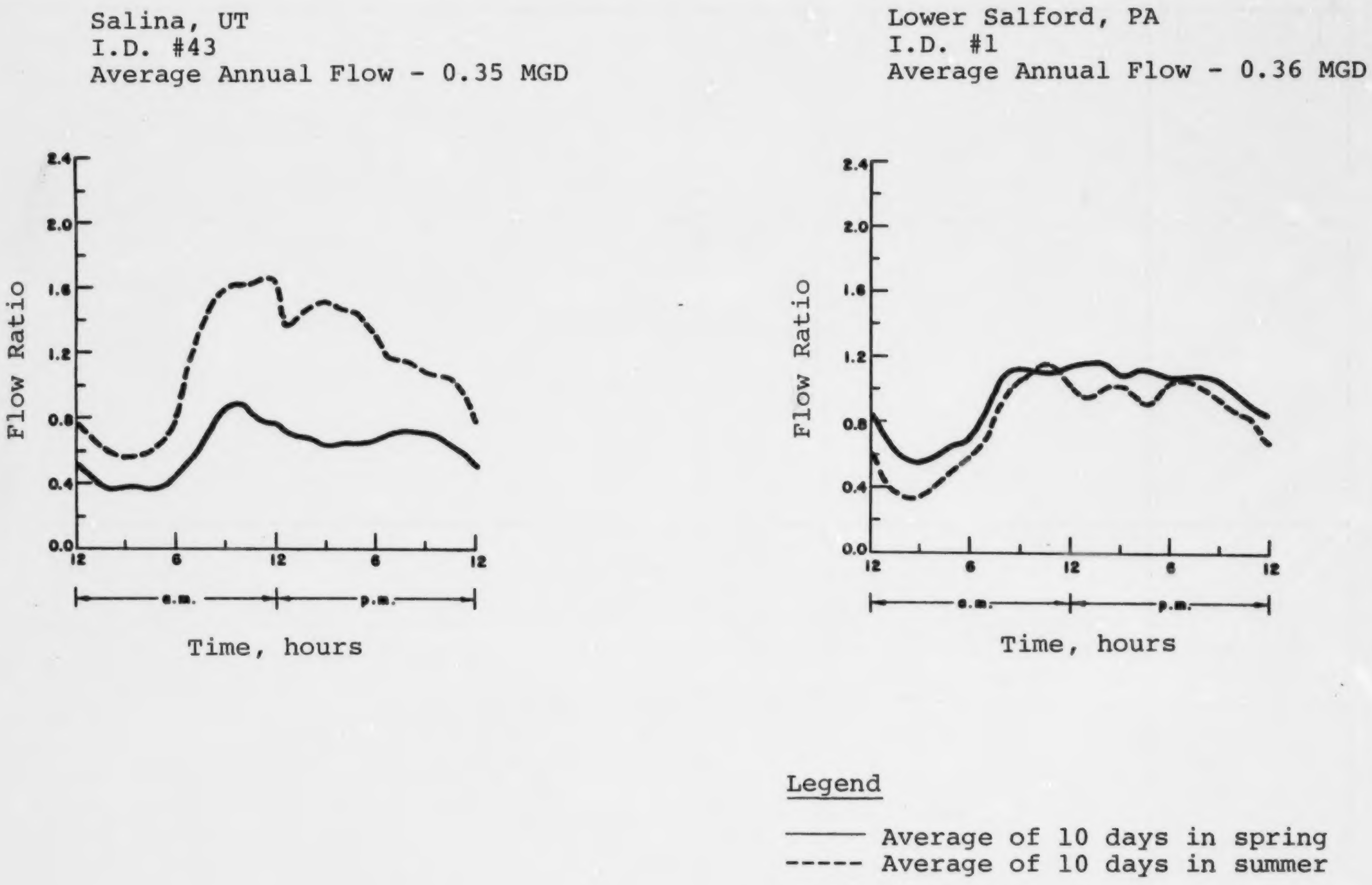

Salina, UT
I.D. #43
Average Annual Flow - 0.35 MGD

Lower Salford, PA
I.D. #1
Average Annual Flow - 0.36 MGD

Figure A-5. Diurnal hydraulic variation for I.D. #43 and #1.

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COMPARATIVE ASSESSMENT FOR MAPLE PLAIN, MN AND SALINA, UT

I. DIURNAL HYDRAULIC VARIATION CURVE

	Maple Plain	Salina
Peaking Factor PF_A (±2σ) - Spring	1.01 (±0.42)	0.90 (±0.20)
- Summer	0.97 (±0.25)	1.65 (±0.30)
Wave Form - Spring	Sharp and Multi-Peak	Typical
- Summer	Typical	Sharp
Seasonal Variation	No	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Shape	None	--
Groundwater Table	None	--

III. CONCLUSION

- Although both systems have 50% industrial flow, different types of industry can exhibit substantial differences in the wave form and seasonality.

- The impact of dissimilar collection system parameters are relatively minor when the percentage of industrial flow is a dominant factor.

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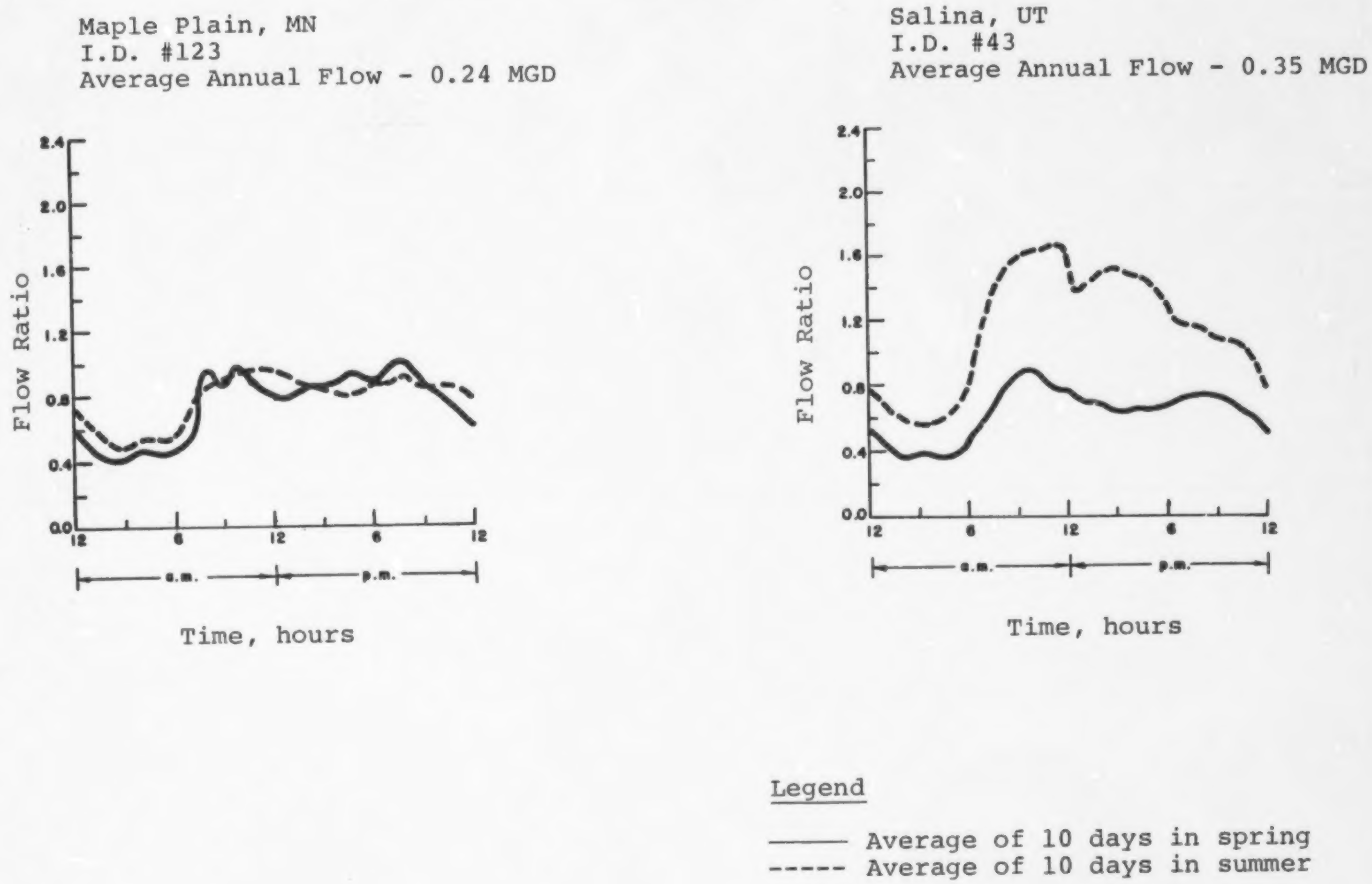


Maple Plain, MN
I.D. #123
Average Annual Flow - 0.24 MGD

Salina, UT
I.D. #43
Average Annual Flow - 0.35 MGD

Legend

——— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-6. Diurnal hydraulic variation for I.D. #123 and #43.

COMPARATIVE ASSESSMENT FOR RICHLYN MANOR, MD AND MONEY CREEK, GA

I. DIURNAL HYDRAULIC VARIATION CURVE

	Richlyn Manor	Honey Creek
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.32 (±1.10)	1.40 (±0.57)
- Summer	1.56 (±2.20)	1.15 (±0.28)
Wave Form - Spring	Multi-Peak	Typical
- Summer	Sharp	Typical
Seasonal Variation	None	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

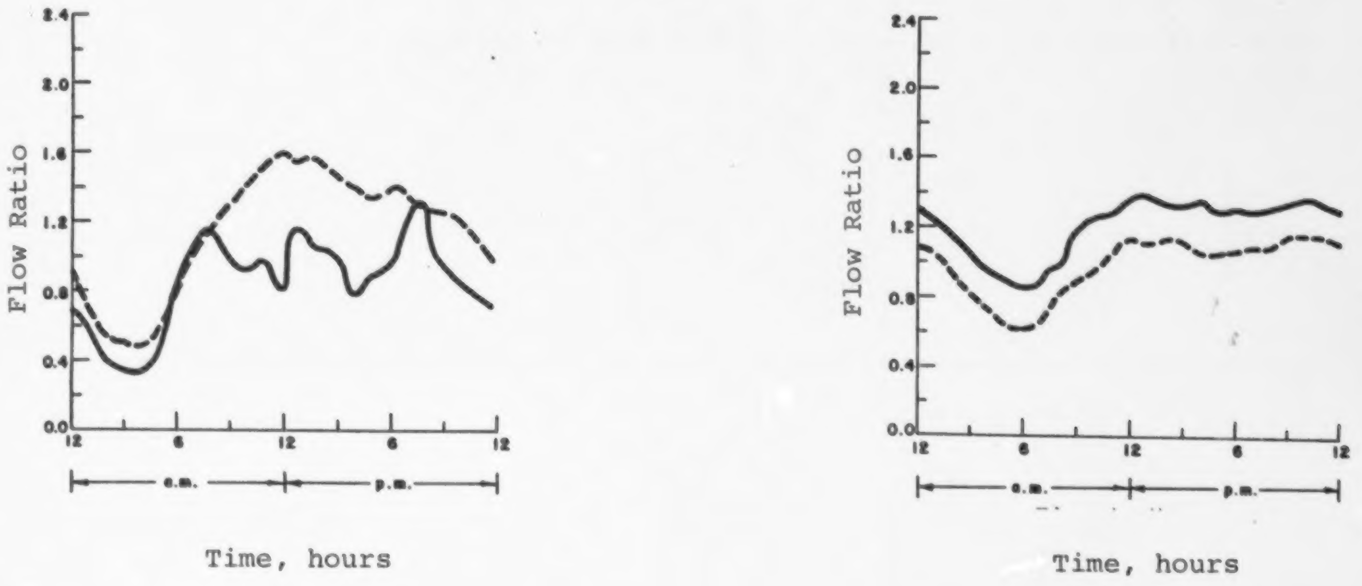
Dissimilar Collection System Parameters	Impact	Description
Topography	None	--
Average Age	Yes	The 45 year old Honey Creek system shows seasonality while the 18 year old Richlyn Manor system does not.

III. CONCLUSION

- An old age and shallow groundwater table system exhibits seasonal variation, while a young age and high groundwater table system does not.

- The sharp and multi-peak wave form in Richlyn Manor is as a result of high intensity and short duration of rainfall (inflow).

- Intensity and duration of rainfall is a major factor and can distort normal diurnal wave forms.



Richlyn Manor, MD
I.D. #9
Average Annual Flow - 0.07 MGD

Honey Creek, GA
I.D. #13
Average Annual Flow - 0.42 MGD

Legend

——— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-7. Diurnal hydraulic variation for I.D. #9 and #13.

TABLE A-3. POTW's AND COLLECTION SYSTEM PARAMETERS
FLOW RANGE: 0.5 - 1.0 MGD

I.D. No.	State	Name	Avg. Annual Flow (Mgd)	Popula-tion	Percent Indust. Contrib.	Avg. Annual Rainfall (In.)	Topography	Soil Type	Shape	Ground water Table	Avg. Age (Yrs.)	No. of Pump-ing Sta-tions	By-Pass
82	NY	Kings Park	0.83	13,000	90 Hospital	42	Rolling	Sand	Cluster	Deep	45	2	No
106	MN	Bayport	0.50	2,100	50	27	Steep	Mix-ture	Narrow	Mixture	40	2	No
122	MN	Chaska	0.85	7,000	12	27	Rolling	Clay	Cluster	Shallow	30	1	No
125	IN	Carmel North	0.73	9,000	10	40	Flat	Clay	Cluster	Shallow	15	5	Yes
127	MI	East Tawas	0.57	3,354	0	40	Flat	Sand	Nucleated	Shallow	50	7	No

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COMPARATIVE ASSESSMENT FOR BAYPORT, MN AND KINGS PARK, NY

I. DIURNAL HYDRAULIC VARIATION CURVE

		Bayport	Kings Park
Peaking Factor			
PF_A ($\pm 2\sigma$)	- Spring	1.50 (±0.55)	1.42 (±0.12)
	- Summer	1.48 (±0.29)	1.86 (±0.17)
Wave Form	- Spring	Sharp	Sharp
	- Summer	Sharp	Sharp
Seasonal Variation		No	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Percent Industrial Contribution	Yes	Both Bayport and Kings Park are institutionally dominated, publicly-owned treatment works. Fifty percent of Bayport flow comes from a prison, while ninety percent of Kings Park flow comes from hospitals. In such institutions it is customary for everyone to perform daily activities at specific times, such as breakfast, shower, lunch, dinner, etc. Hence, they both have sharp steep consistent peaks. The difference in spring

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		and summer flow at Kings Park was the result of the expansion during the two period of flow records. The summer curve shape is essentially the same, and is simply elevated.
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Groundwater Table	None	-- --

III. CONCLUSION

- An institutional dominated system can exhibit a sharp wave form.

- The rest of the collection system parameters tend to be the minor when the percent industrial or institutional contribution is the major factor affecting the wave form.

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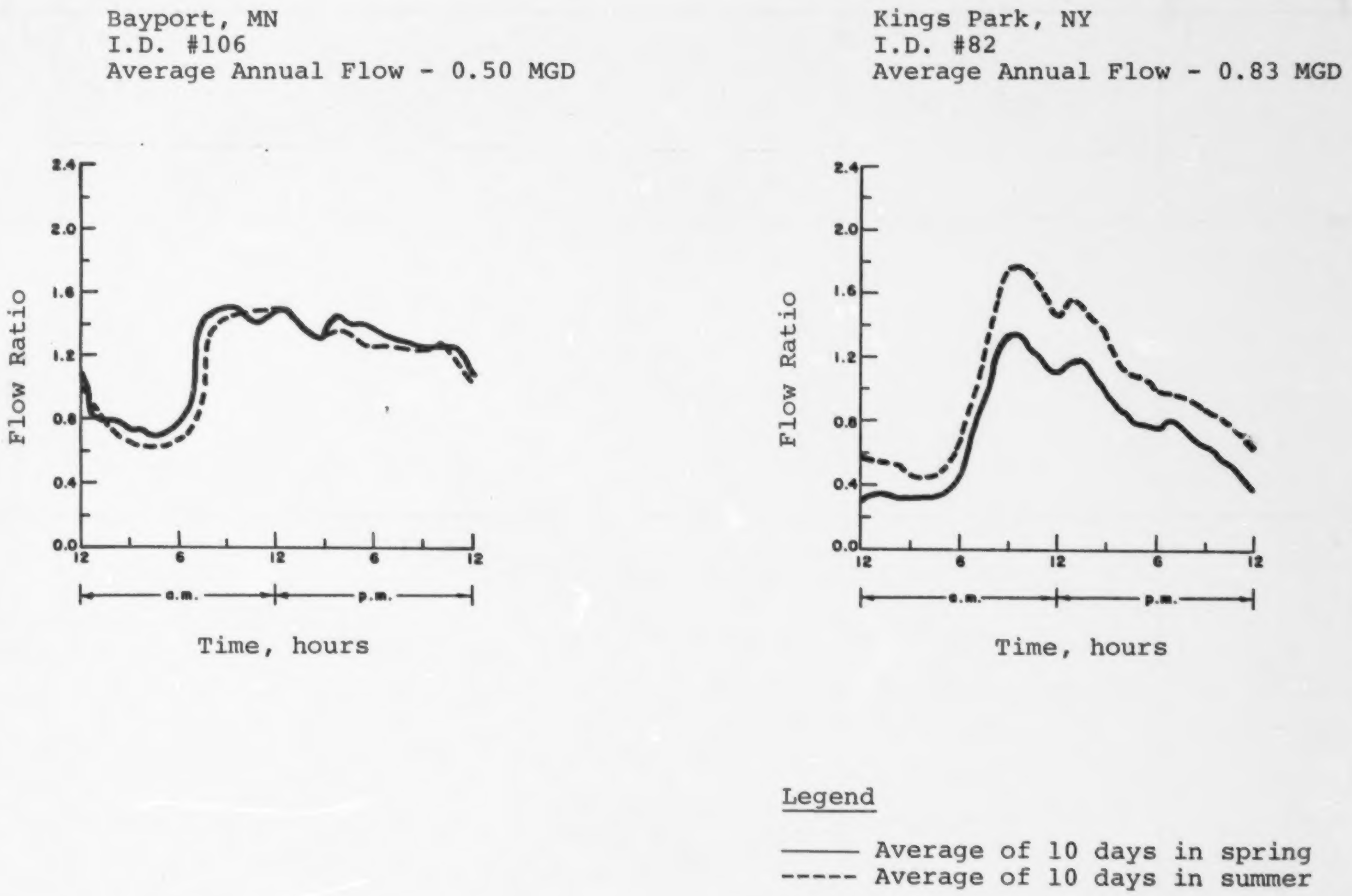

Bayport, MN
I.D. #106
Average Annual Flow - 0.50 MGD

Kings Park, NY
I.D. #82
Average Annual Flow - 0.83 MGD

Figure A-8. Diurnal hydraulic variation for I.D. #106 and #82.

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COMPARATIVE ASSESSMENT FOR CHASKA, MN AND EAST TAWAS, MI

I. DIURNAL HYDRAULIC VARIATION CURVE

	Chaska	East Tawas
Peaking Factor		
PF_A (±2σ) - Spring	1.45 (±0.15)	1.30 (±0.55)
- Summer	1.00 (±0.14)	0.90 (±0.46)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	Yes	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Shape	None	--
Number of Pumping Stations	None	--

III. CONCLUSION

- An old age and high groundwater table system demonstrates seasonal variation (infiltration). In this case, both systems exhibit these characteristics.

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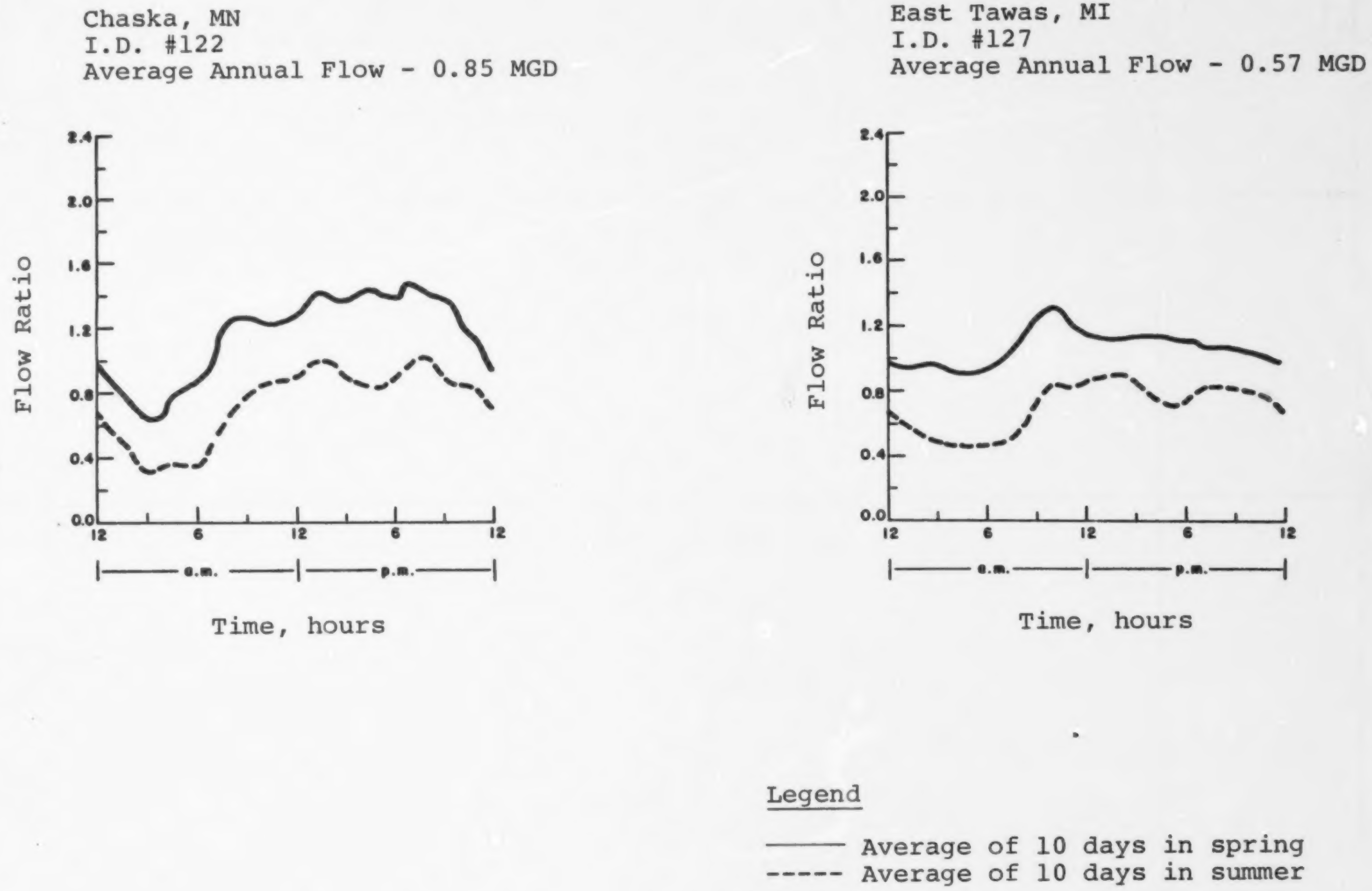


Figure A-9. Diurnal hydraulic variation for I.D. #122 and #127.

COMPARATIVE ASSESSMENT FOR CHASKA, MN AND BAYPORT, MN

I. DIURNAL HYDRAULIC VARIATION CURVE

	Chaska	Bayport
Peaking Factor		
PF_A (±2σ) - Spring	1.45 (±0.15)	1.50 (±0.55)
- Summer	1.00 (±0.14)	1.48 (±0.29)
Wave Form - Spring	Typical	Sharp
- Summer	Typical	Sharp
Seasonal Variation	Yes	No

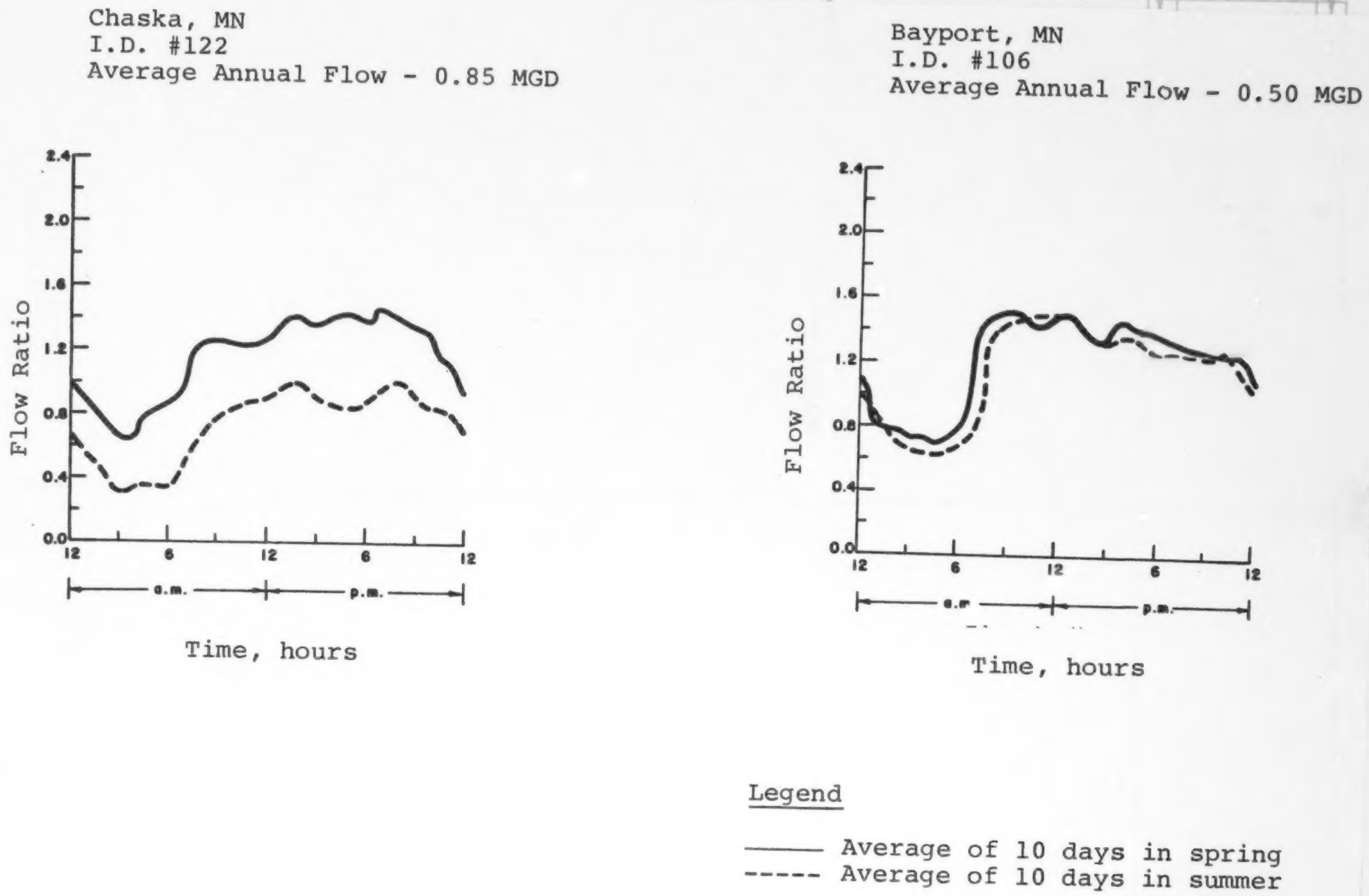
II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Percent Industrial Contribution	Yes	Bayport has 50% from a correctional institution and displays a sharp wave form.
Topography	None	--
Soil Type	None	--
Shape	None	--
Groundwater Table	Yes	Marked seasonality is found in the high groundwater table system at Chaska.

III. CONCLUSION

- The percent industrial contribution exhibits a significant influence in the shape of the wave form as well as the peaking factor.

- Old age and high groundwater table appear to be dominant factors affecting the seasonal variation of the curve.



Chaska, MN
I.D. #122
Average Annual Flow - 0.85 MGD

Bayport, MN
I.D. #106
Average Annual Flow - 0.50 MGD

Legend

——— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-10. Diurnal hydraulic variation for I.D. #122 and #106.

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COMPARATIVE ASSESSMENT FOR CARMEL NORTH, IN AND EAST TWAS, MI

I. DIURNAL HYDRAULIC VARIATION CURVE

	Carmel North	East Tawas
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.15 (±0.38)	1.30 (±0.55)
- Summer	1.35 (±0.35)	0.90 (±0.46)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	No	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Soil Type	None	--
Shape	None	--
Average Age	Yes	The old age system in East Tawas exhibits infiltration in the seasonal variation of the wave form.
Bypass	None	--

III. CONCLUSION

- Old age appears to be a major factor influencing seasonality (infiltration).

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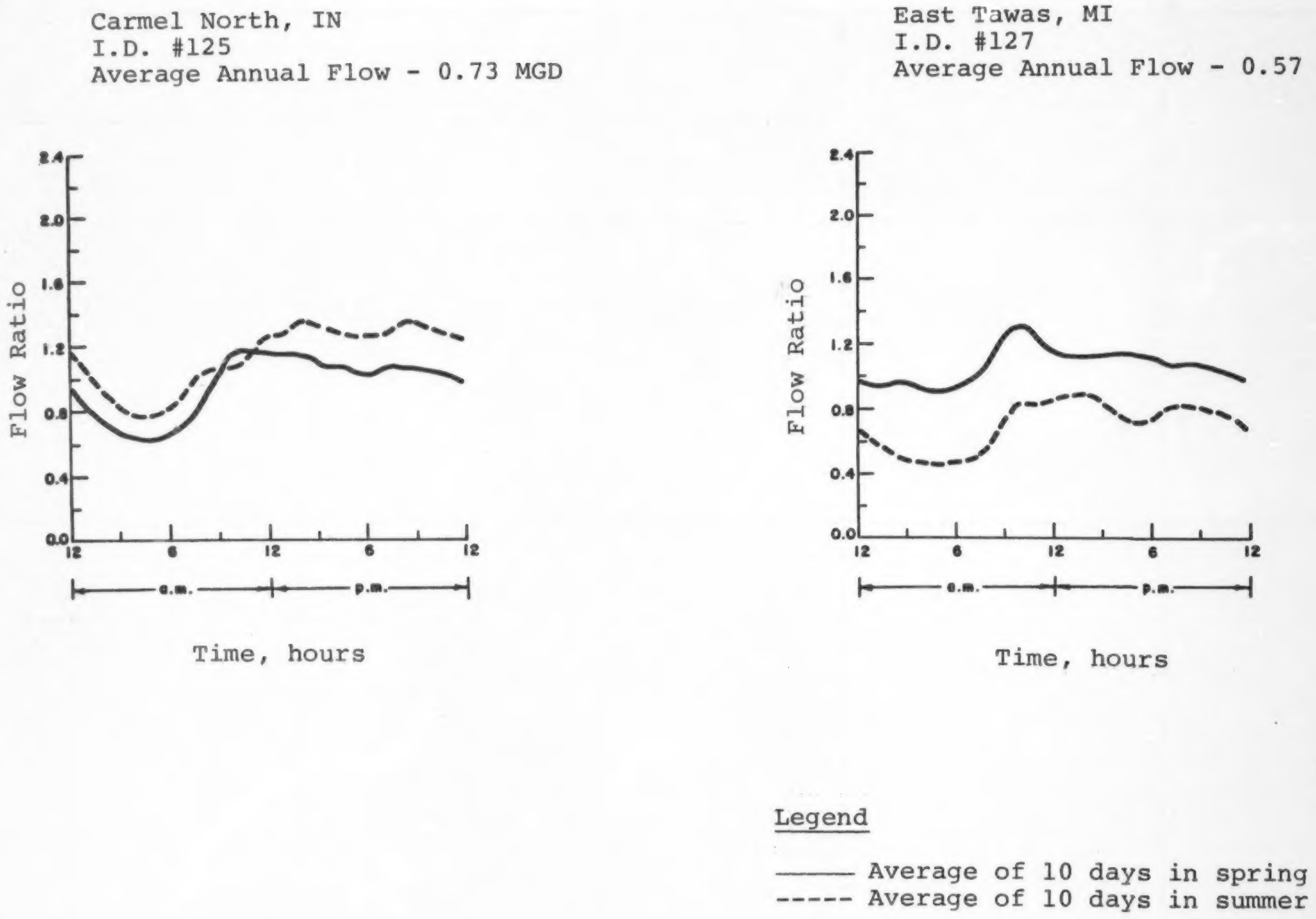

Carmel North, IN
I.D. #125
Average Annual Flow - 0.73 MGD

East Tawas, MI
I.D. #127
Average Annual Flow - 0.57 MGD

Legend

——— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-11. Diurnal hydraulic variation for I.D. #125 and #127.

TABLE A-4. POTW's AND COLLECTION SYSTEM PARAMETERS
FLOW RANGE: 1.0 - 5.0 MGD

I.D. No.	State	Name	Avg. Annual Flow (Mgd)	Population	Percent Indust. Contrib.	Avg. Annual Rainfall (In.)	Topography	Soil Type	Shape	Ground water Table	Avg. Age (Yrs.)	No. of Pumping Stations	By-Pass
12	GA	Pole Bridge	1.58	23,000	15	48	Rolling	Clay	Narrow	Shallow	45	1	No
14	GA	Shoel Creek	2.69	29,000	5	48	Rolling	Clay	Narrow	Shallow	45	1	Yes
33	WA	Pullman	3.1	24,000	95	20	Rolling	Clay	Cluster	Shallow	40	1	Yes
35	NJ	Gloucester	1.6	14,500	10	40	Flat	Mixture	Nucleated	Shallow	70	8	Yes
50	CO	Broomfield	2.5	23,000	≤ 5	14	Moderate	Clay	Cluster	Deep	20	2	No
57	SD	Watertown	2.7	18,000	≤ 5	21	Rolling	Sand	Nucleated	Shallow	75	37	No
64	NY	Belgrave	1.59	13,000	≤ 5	42	Moderate	Clay	Cluster	Mixture	45	0	No
73	NY	Freeport	4.2	41,000	≤10	42	Flat	Sand	Narrow	Shallow	45	5	No
105	MN	Anoke	1.90	21,800	28	27	Moderate	Sand	Cluster	Deep	60	114	No
126	IN	Carmel South	1.3	12,000	0	40	Flat	Clay	Narrow	Shallow	10	8	Yes
145	CA	La Salina	3.25	22,500	0	12	Flat	Mixture	Cluster	Deep	49	13	No

COMPARATIVE ASSESSMENT FOR POLE BRIDGE, GA AND SHOEL CREEK, GA

I. DIURNAL HYDRAULIC VARIATION CURVE

	Pole Bridge	Shoel Creek
Peaking Factor		
PF_A ($\pm 2\sigma^*$) - Spring	0.90 (±0.44)	1.13 (±0.05)
- Summer	1.05 (±0.12)	1.20 (±0.17)
Wave Form - Spring	Flat	Flat
- Summer	Flat	Flat
Seasonal Variation	No	NO

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Bypass	Yes	The flat curve at Shoel Creek is due to the fact that is bypasses sewage to another plant, whenever the flow exceeds 3 mgd (or a flow ratio 1.2).

III. CONCLUSION

- The existing of bypass at a flow ratio of 1.2 results in a flat wave form (equalization effect) and a reduced peaking factor.

- Large influent interceptors and the wet well in the Pole Bridge treatment plant have an equalization affect which limits peaking.

- Old age and high groundwater table did not show a seasonal variation; could be attributed to equalization effect.

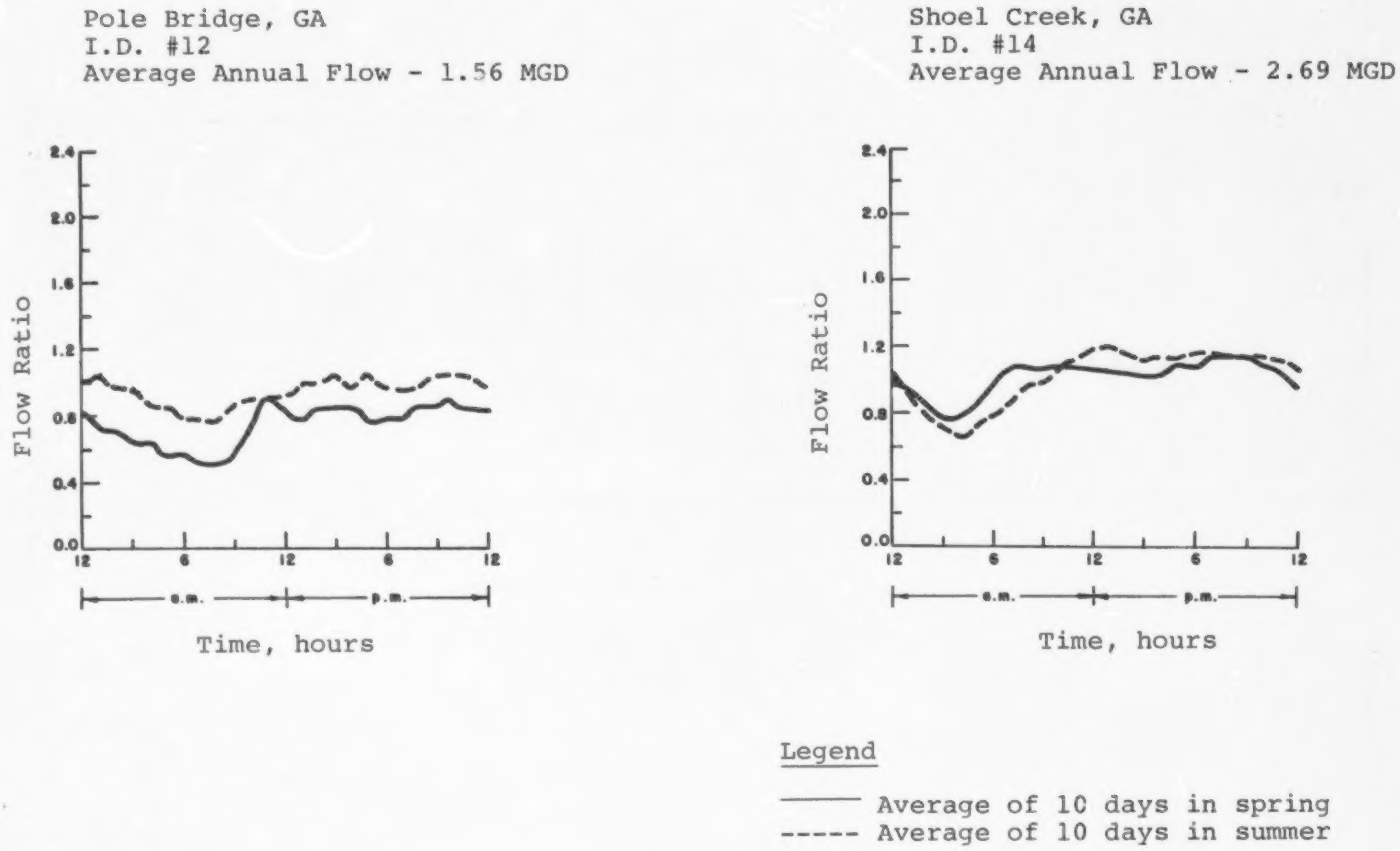

Figure A-12. Diurnal hydraulic variation for I.D. #12 and #14.

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COMPARATIVE ASSESSMENT FOR PULLMAN, WA AND FREEPORT, NY

I. DIURNAL HYDRAULIC VARIATION CURVE

	Pullman	Freeport
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	2.17 (±0.50)	1.60 (±0.48)
- Summer	1.10 (±0.21)	1.15 (±0.24)
Wave Form - Spring	Sharp	Typical
- Summer	Typical	Typical
Seasonal Variation	Yes	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Percent Industrial Contribution	Yes	Pullman is an institution dominated system and shows greater peaking factor and sharp wave form during spring (more school enrollment).
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Bypass	None	--

III. CONCLUSION

- Pullman is a university town where the summer flows would be expected to be lower than the spring flows (i.e. less enrollment in summer school). Therefore, the seasonal variation is the result of old age, high groundwater table and seasonal population.

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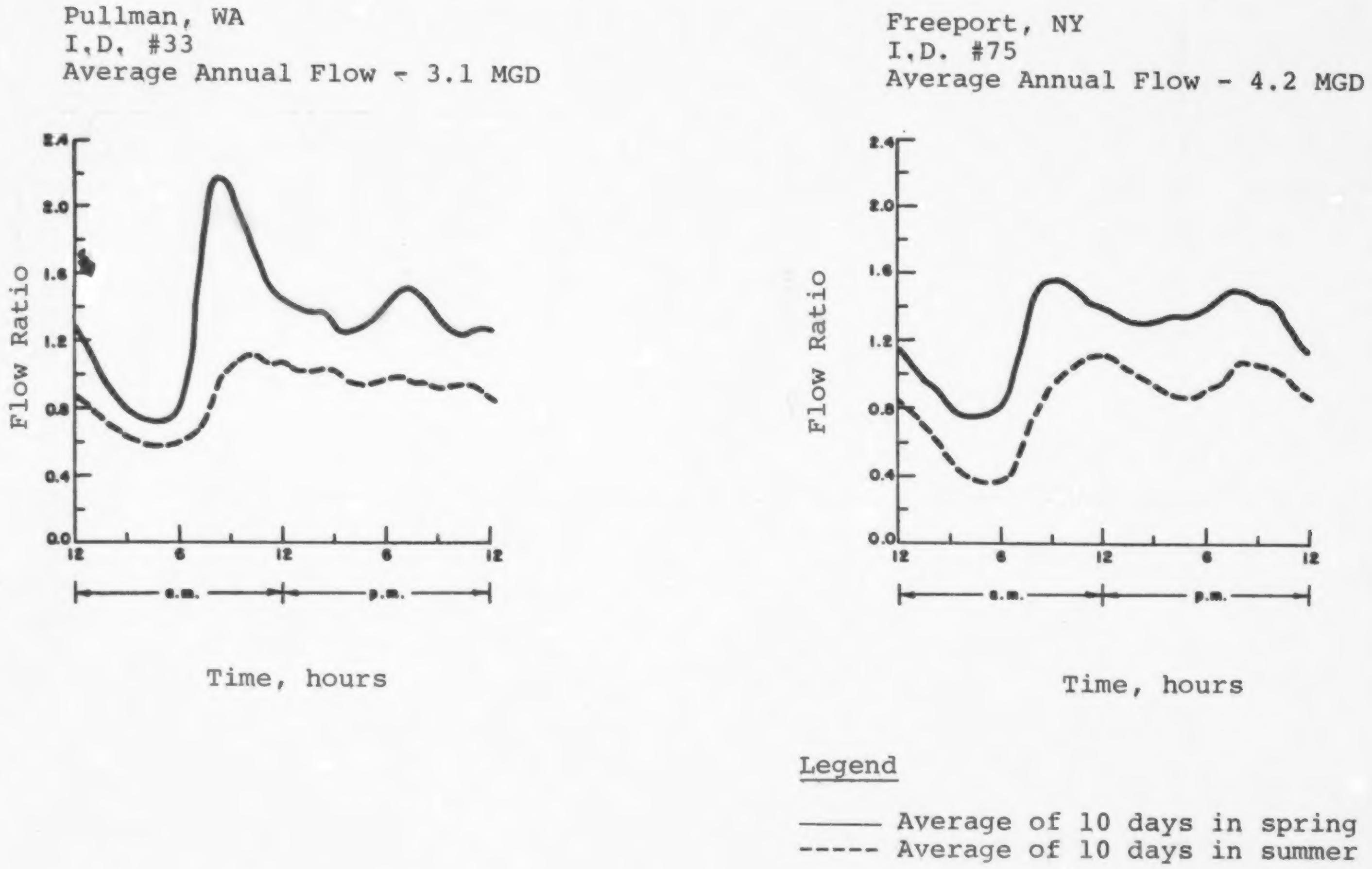
- The sharp wave form shown is similar to Bayport and Kings Park institutional dominated systems; a result of specific discharge schedules.

- In Freeport, all of the following factors account for the substantial seasonal variation and higher peaking ratios: sand soil type; high rainfall; high groundwater table; and, old age.



Pullman, WA
I,D, #33
Average Annual Flow - 3.1 MGD

Freeport, NY
I.D. #75
Average Annual Flow - 4.2 MGD

Figure A-13. Diurnal hydraulic variation for I.D. #33 and #75.

COMPARATIVE ASSESSMENT FOR BELGRAVE, NY AND ANOKE, MN

I. DIURNAL HYDRAULIC VARIATION CURVE

	Belgrave	Anoke
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.32 (±0.20)	1.45 (±0.24)
- Summer	1.46 (±0.42)	1.41 (±0.17)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	No	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Percent Industrial Contribution	None	--
Average Annual Rainfall	None	--
Soil Type	None	--
Groundwater Table	None	--
Number of Pumping Stations	None	--

III. CONCLUSION

The similar wave forms and peaking ratios led to the following conclusions:

- The difference between collection systems such as percent industrial contribution (28% versus 50%), average annual rainfall (42" versus 27"), Soil type (clay versus sand), groundwater table (mixture versus deep), and number of pumping stations (0 versus 14), did not show a notable influence on either the wave form or the peaking factor.

- Although both systems are old, neither had a high groundwater table and did not exhibit seasonal variation.

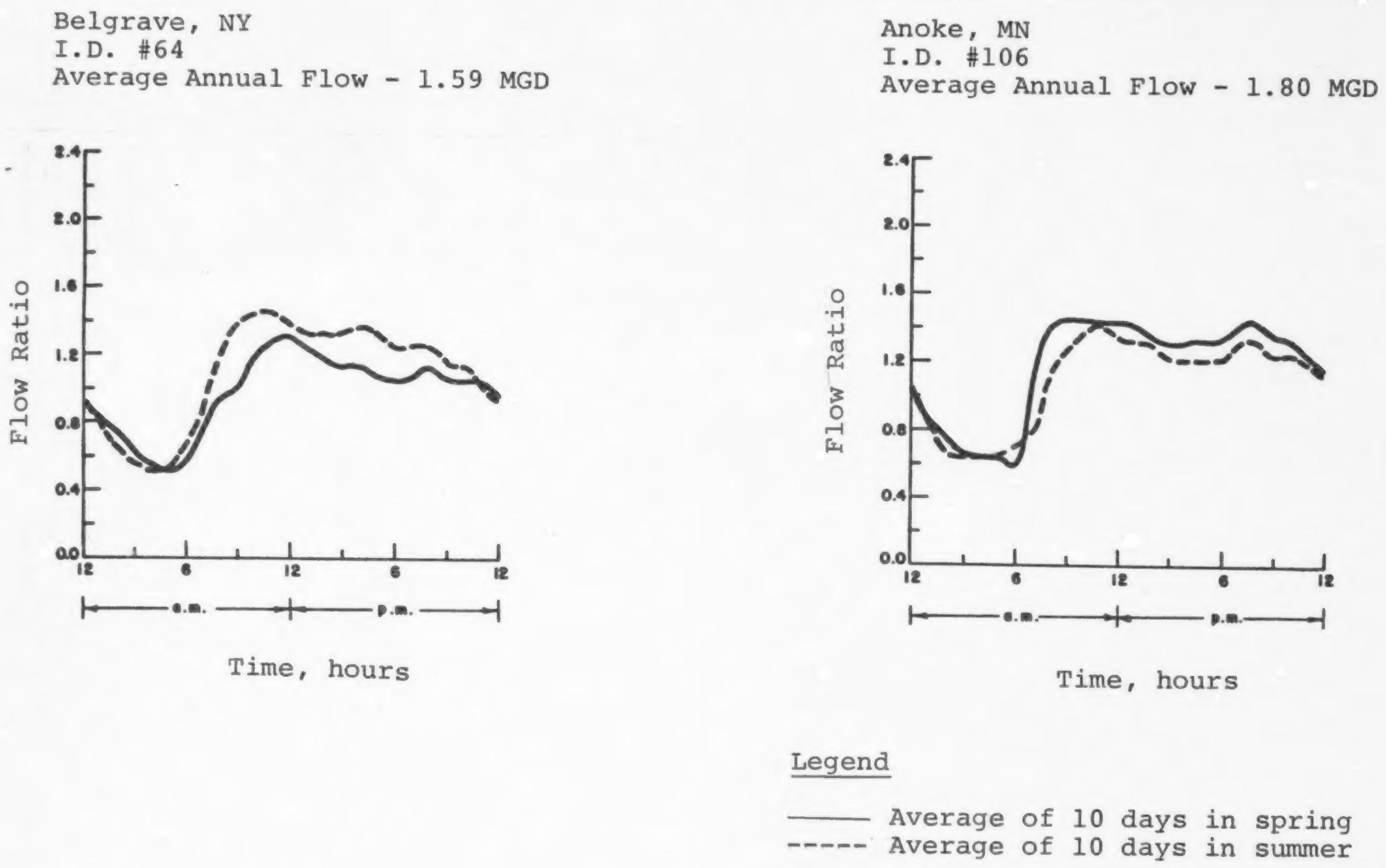


Figure A-14. Diurnal hydraulic variation for I.D. #64 and #106.

COMPARATIVE ASSESSMENT FOR BROOMFIELD, CO AND GLOUSCESTER, NJ

I. DIURNAL HYDRAULIC VARIATION CURVE

	Broomfield	Gloucester
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.25 (±0.43)	1.13 (±0.71)
- Summer	1.25 (±0.22)	1.46 (±0.12)
Wave Form - Spring	Typical	Flat
- Summer	Typical	Typical
Seasonal Variation	No	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Shape	None	--
Groundwater Table	None	--
Average Age	None	--
No. of Pumping Station	None	--
Bypass	None	--

III. CONCLUSION

- Since Glouscester is a combined sewer system and has bypass line in its collection system, the flat spring curve resulted from equalization effect of the bypass and the summer peaks were due to rainfall inflow.

- The lack of seasonality in Broomfield indicates that there is little infiltration in this

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system. This is expected since the groundwater table is low; the soil type is clay (impervious); and the average annual rainfall is low (14").

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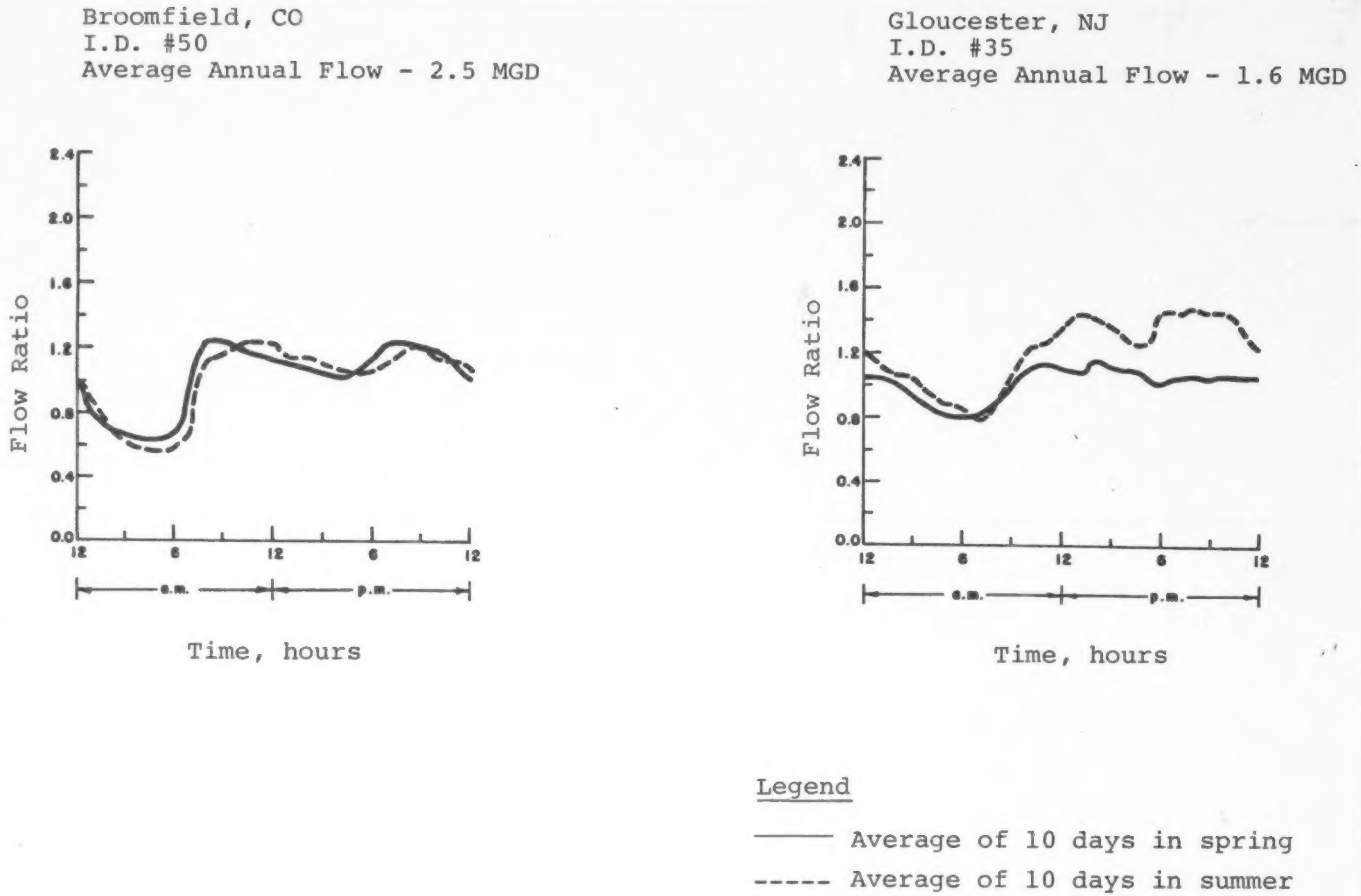

Figure A-15. Diurnal hydraulic variation for I.D. #50 and #35.

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COMPARATIVE ASSESSMENT FOR WATERTOWN, SD AND LA SALINA, CA

I. DIURNAL HYDRAULIC VARIATION CURVE

	Watertown	La Salina
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.40 (±1.50)	1.49 (±0.17)
- Summer	1.18 (±1.13)	1.45 (±0.13)
Wave Form - Spring	Typical	Sharp
- Summer	Typical	Sharp
Seasonal Variation	Yes	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Shape	Yes	The clustered shaped La Salina system exhibits a sharp wave form.
Groundwater Table	Yes	Watertown system is constructed in a high groundwater table and exhibits seasonal variation.
Number of Pumping Stations	None	--

III. CONCLUSION

- The seasonal variation exhibited by Watertown is due to the combined factors of the high groundwater table and the old age of the system.

- The sharp wave form can be due to the clustered shape collection system.

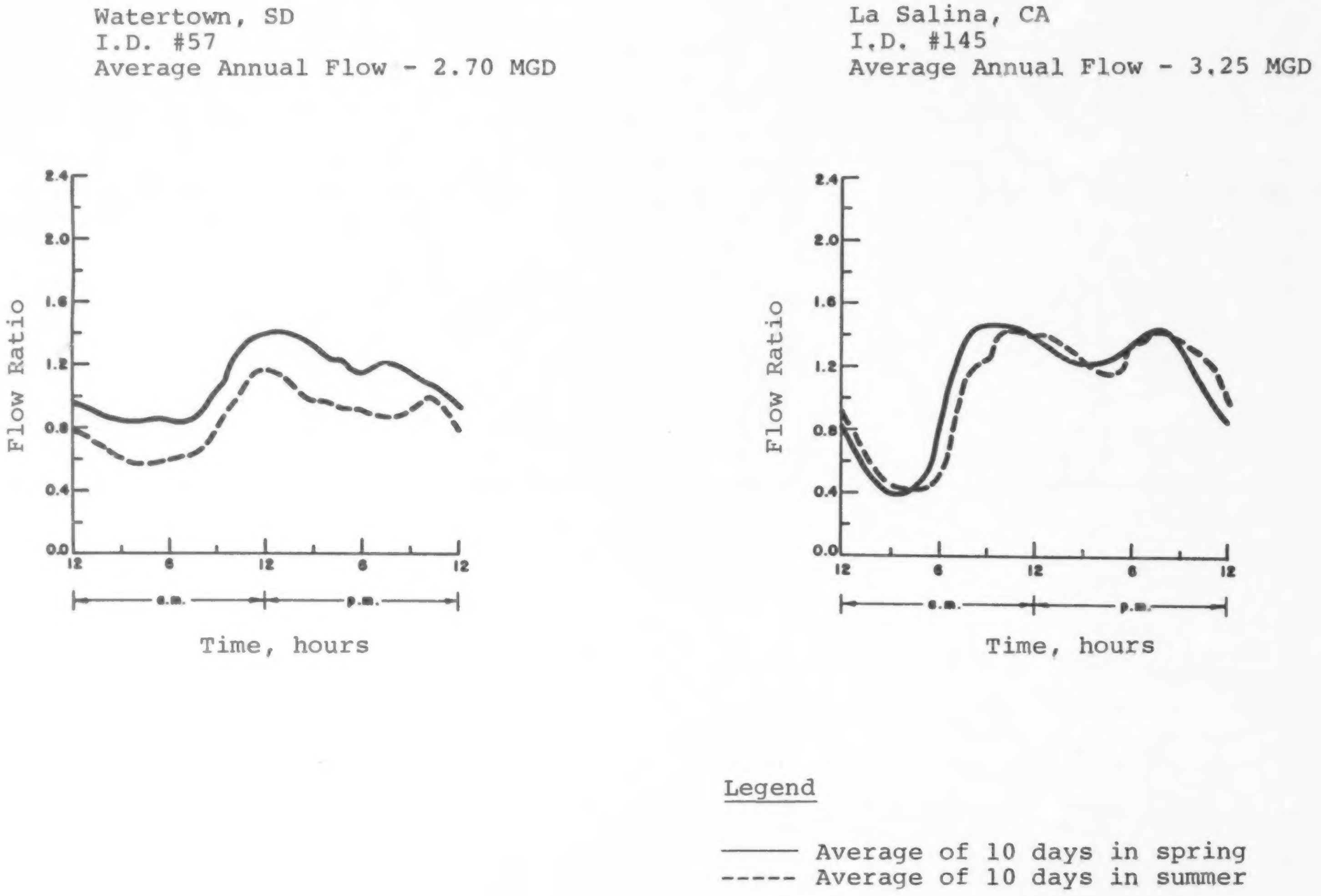

Figure A-16. Diurnal hydraulic variation for I.D. #57 and #145.

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COMPARATIVE ASSESSMENT FOR WATERTOWN, SD AND CARMEL SOUTH, IN

I. DIURNAL HYDRAULIC VARIATION CURVE

	Watertown	Carmel South
Peaking Factor		
PF_A (±2σ) - Spring	1.40 (±1.50)	1.40 (±0.35)
- Summer	1.18 (±1.13)	0.90 (±0.39)
Wave Form - Spring	Typical	Sharp
- Summer	Typical	Typical
Seasonal Variation	Yes	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Age	None	--
Bypass	None	--

III. CONCLUSION

- Seasonal variation for Watertown is due to the high groundwater table and old system; that for Carmel South results from the high groundwater table.

- Carmel South was subjected to intense rainfalls during the spring flow period, resulting in the sharp wave form.

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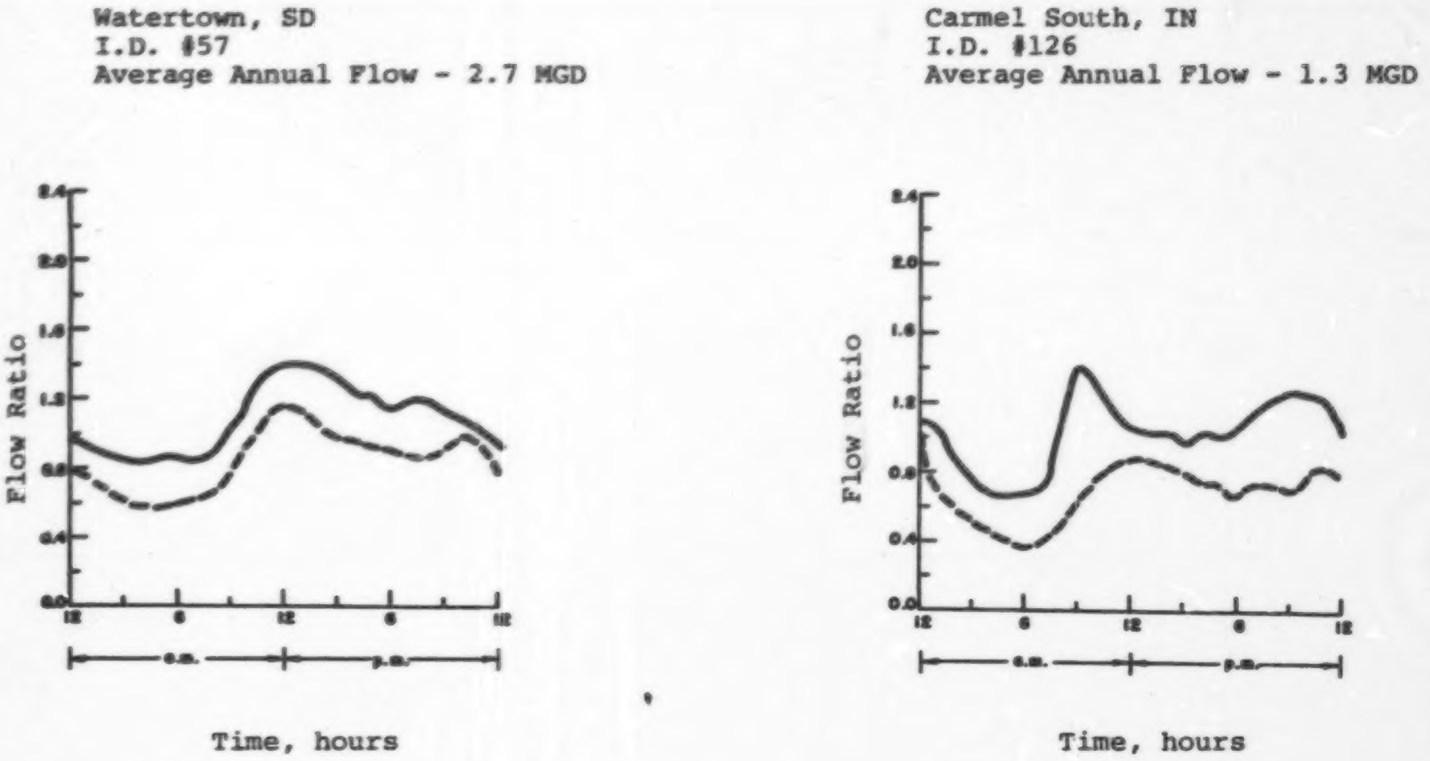
Watertown, SD
I.D. #57
Average Annual Flow - 2.7 MGD

Carmel South, IN
I.D. #126
Average Annual Flow - 1.3 MGD

Legend

—— Averagc of 10 days in spring
----- Average of 10 days in summer

Figure A-17. Diurnal hydraulic variation for I.D. #57 and #126.

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TABLE A-5. POTW's AND COLLECTION SYSTEM PARAMETERS
FLOW RANGE: 5.0 - 10.0 MGD

I.D. No.	State	Name	Avg. Annual Flow (Mgd)	Population	Percent Indust. Contrib.	Avg. Annual Rainfall (In.)	Topography	Soil Type	Shape	Ground water Table	Avg. Age (Yrs.)	No. of Pumping Stations	By-Pass
10	CN	City of West Haven	7.3	57,000	≤ 5	43	Steep	Clay	Cluster	Shallow	39	15	No
32	IA	Ames	5.0	45,000	40	32	Steep	Clay	Cluster	Deep	24	10	Yes
51	KS	Lawrence WWTP	5.0	55,000	40	35	Rolling	Clay	Cluster	Shallow	25	21	No
58	TX	Guadalupe-Blanco River	5.0	58,000	≤ 20	36	Flat	Clay	Cluster	Deep	84	14	No
59	TX	Midland	6.2	80,000	≤ 5	15	Flat	Sand	Nucleated	Deep	25	0	Yes

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COMPARATIVE ASSESSMENT FOR GUADALUPE-BLANCO RIVER, TX AND LAWRENCE, KS

I. DIURNAL HYDRAULIC VARIATION CURVE

	Guadalupe-Blanco River	Lawrence
Peaking Factor		
PF_A (± 2σ) - Spring	0.95 (±0.39)	1.59 (±0.27)
- Summer	1.10 (±0.24)	1.08 (±0.25)
Wave Form - Spring	Flat	Typical
- Summer	Flat	Typical
Seasonal Variation	No	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Topography	Yes	Guadalupe-Blanco River is a flat system which exhibits a flat diurnal wave form.
Groundwater Table	Yes	Lawrence was constructed in a high groundwater table and experiences seasonal variation.
Average Age	None	--

III. CONCLUSION

- The flat wave form and low peaking ratio in Guadalupe-Blanco River could result from the flat topography; however, a storage tank prior to the flow measurement is probably the primary reason for the equalization effect and low peaking factors exhibited.

- The seasonality of Lawrence is due to the high groundwater table.

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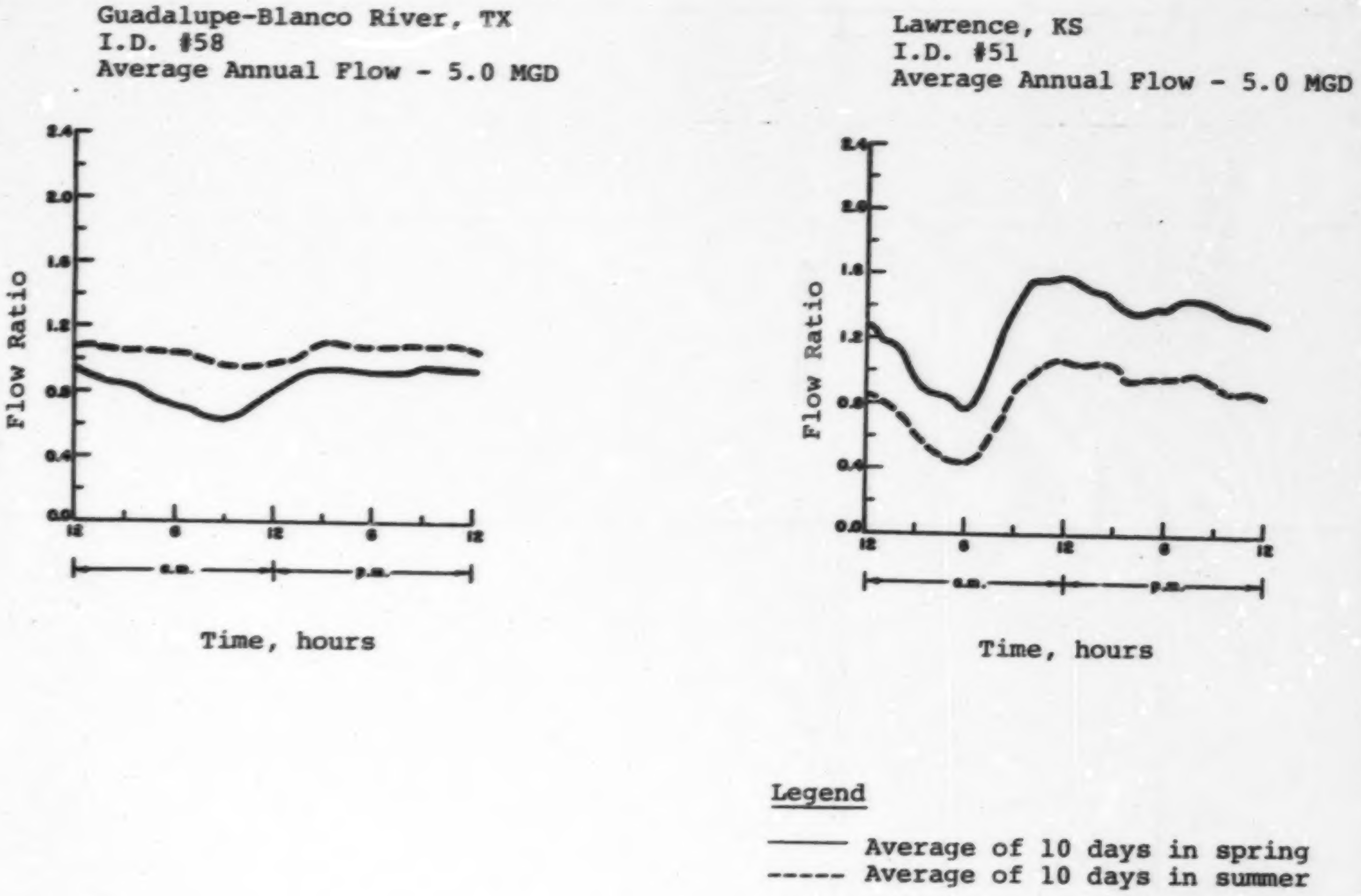

Figure A-18. Diurnal hydraulic variation for I.D. #58 and #51.

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COMPARATIVE ASSESSMENT FOR AMES, IA AND WEST HAVEN, CN

I. DIURNAL HYDRAULIC VARIATION CURVE

	Ames	West Haven
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.38 (±0.36)	1.22 (±0.20)
- Summer	1.05 (±0.11)	1.20 (±0.28)
Wave Form - Spring	Typical	Flat
- Summer	Typical	Typical
Seasonal Variation	Yes	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Groundwater Table	None	--
Average Age	None	--
Bypass	None	--

III. CONCLUSION

- No reason was determined for the flat spring curve and lack of seasonality for the system having a high groundwater table, old age, steep topography, and cluster shape in West Haven.

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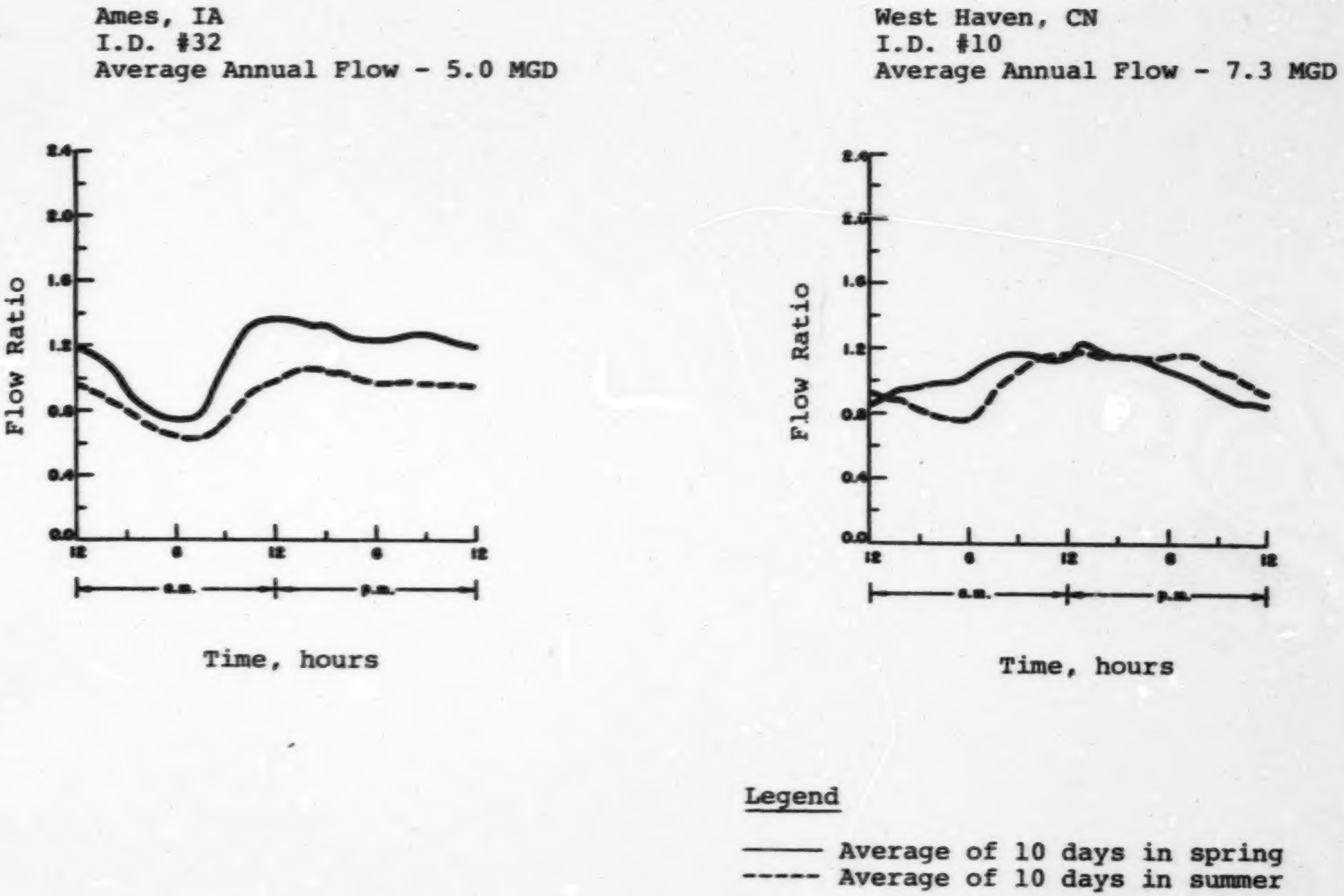

Ames, IA
I.D. #32
Average Annual Flow - 5.0 MGD

West Haven, CN
I.D. #10
Average Annual Flow - 7.3 MGD

Legend

—— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-19. Diurnal hydraulic variation for I.D. #32 and #10.

COMPARATIVE ASSESSMENT FOR AMES, IA AND LAWRENCE, KS

I. DIURNAL HYDRAULIC VARIATION CURVE

	Ames	Lawrence
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.38 (±0.36)	1.58 (±0.27)
- Summer	1.05 (±0.11)	1.08 (±0.25)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	Yes	Yes

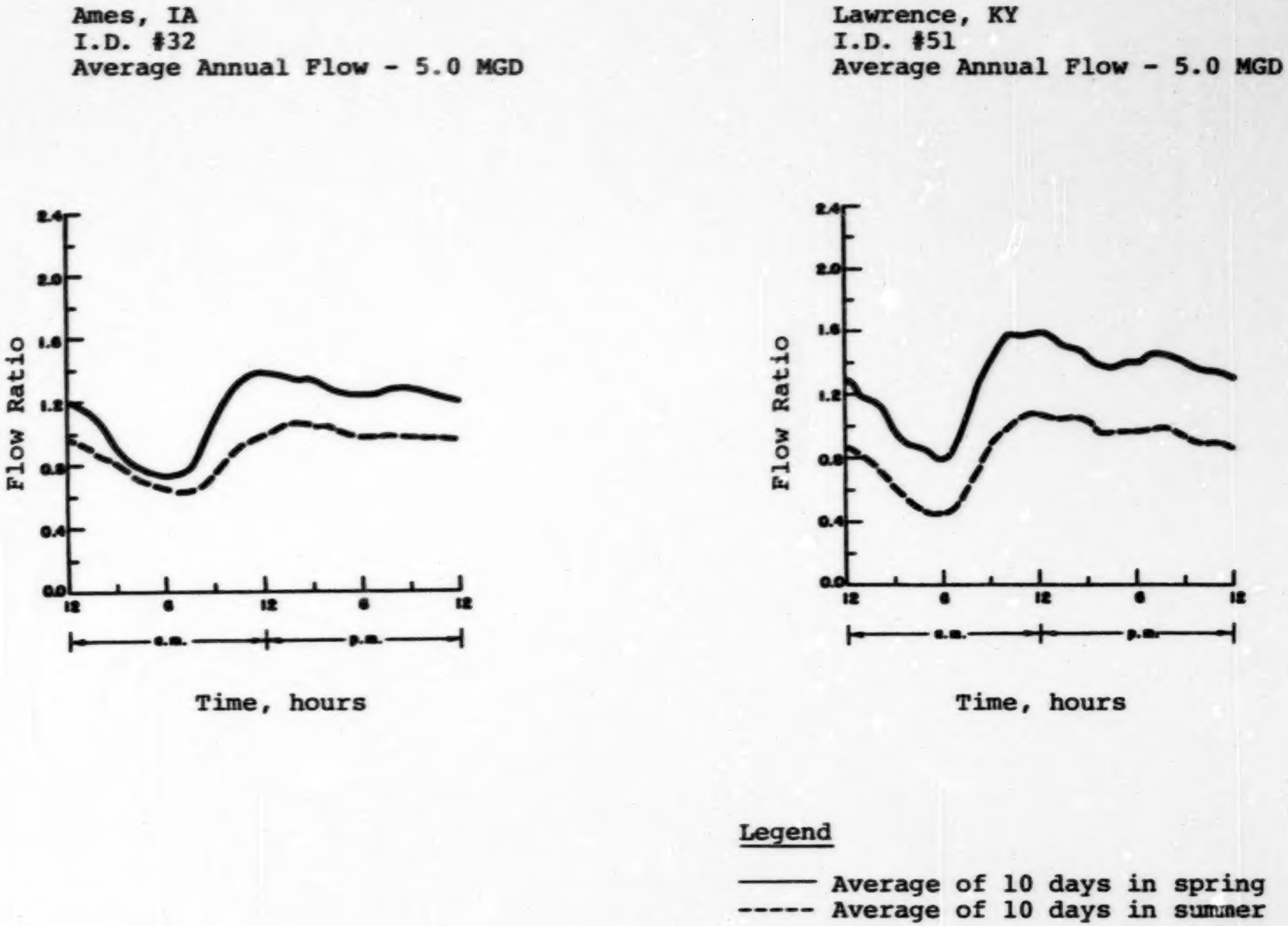
II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Topography	None	--
Groundwater Table	Yes	Lawrence exhibits greater seasonal variation
Number of Pumping Stations	None	--
Bypass	Yes	Ames has a bypass line and exhibits a smoother curve than that of Lawrence where no bypass line exists in the collection system.

III. CONCLUSION

- Ames receives approximately 30% of its flow from a university and a 10% industrial contribution. These two factors account for the seasonal variation in flow even though the groundwater table is low.

- Lawrence has approximately 20% industrial flow, a large influent from a school population (20% of the flow), and a high groundwater table. These three factors influence seasonality.


Ames, IA
I.D. #32
Average Annual Flow - 5.0 MGD

Lawrence, KY
I.D. #51
Average Annual Flow - 5.0 MGD

Legend

——— Average of 10 days in spring
----- Average of 10 days in summer

Figure A-20. Diurnal hydraulic variation for I.D. #32 and #51.

COMPARATIVE ASSESSMENT FOR AMES, IA AND MIDLAND, TX

I. DIURNAL HYDRAULIC VARIATION CURVE

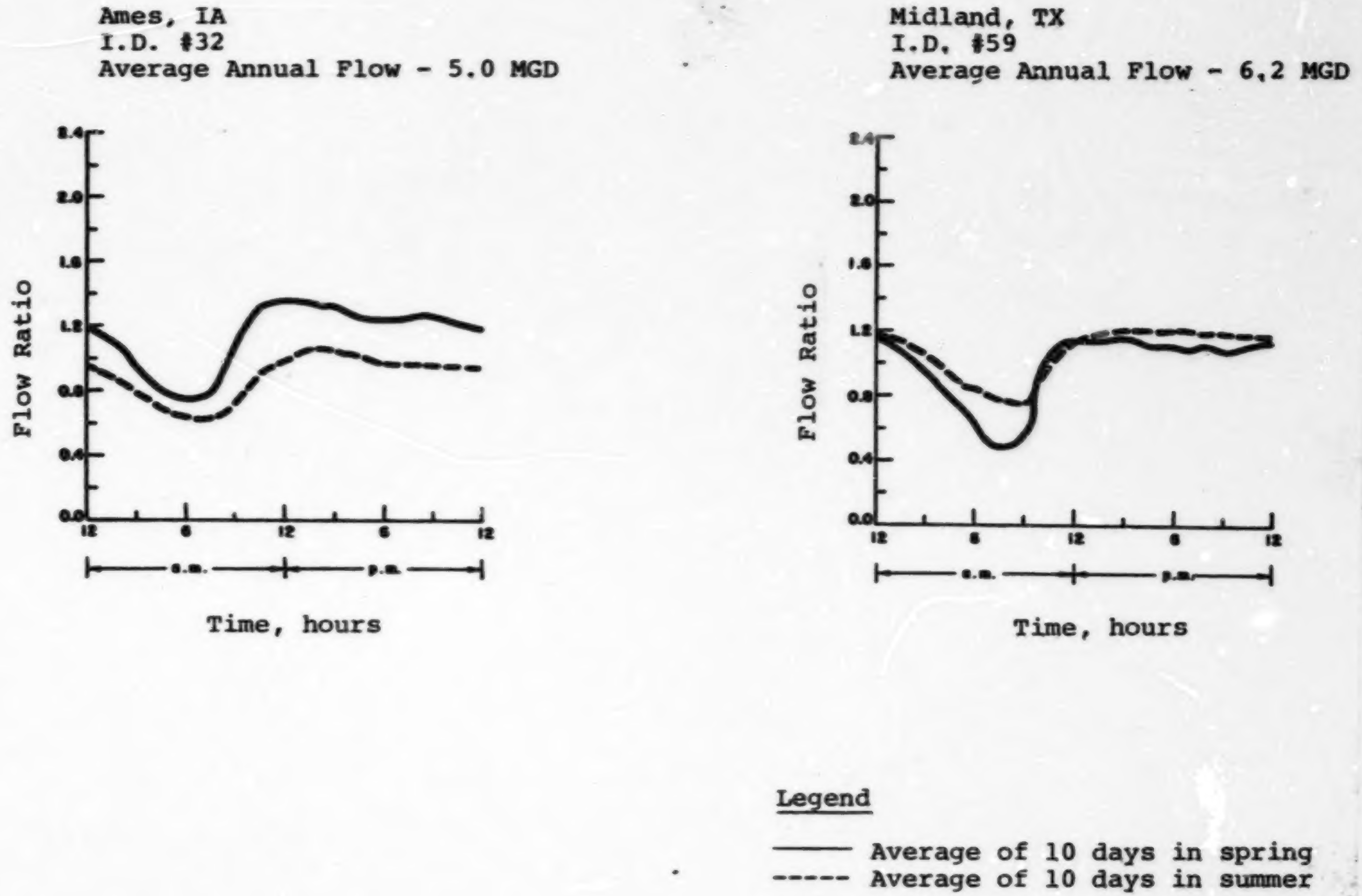
	Ames	Midland
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.38 (±0.36)	1.18 (±0.19)
- Summer	1.05 (±0.11)	1.20 (±0.04)
Wave Form - Spring	Typical	Sharp
- Summer	Typical	Typical
Seasonal Variation	Yes	No

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Soil Type	None	--
Number of Pumping Stations	None	--

III. CONCLUSION

- Average annual rainfall, topography, soil type and number of pumping stations are factors which, by themselves, do not significantly influence peaking.



Ames, IA
I.D. #32
Average Annual Flow - 5.0 MGD

Midland, TX
I.D. #59
Average Annual Flow - 6.2 MGD

Figure A-21. Diurnal hydraulic variation for I.D. #32 and #59.

TABLE A-6. POTW's AND COLLECTION SYSTEM PARAMETERS
FLOW RANGE: ABOVE 10 MGD

I.D. No.	State	Name	Avg. Annual Flow (Mgd)	Population	Percent Indust. Contrib.	Avg. Annual Rainfall (In.)	Topography	Soil Type	Shape	Ground water Table	Avg. Age (Yrs.)	No. of Pumping Stations	By-Pass
29	OH	Toledo	78.0	420,000	28	31	Flat	Mixture	Nucleated	Shallow	60	34	Yes
30	IL	Greater Peoria	30.0	170,000	31	35	Rolling	Clay	Narrow	Mixture	50	3	Yes
71	NY	Bay Park	63.9	560,000	10	42	Flat	Mixture	Narrow	Shallow	35	21	No
107	MN	Blue Lake	13.0	115,000	15	27	Rolling	Mixture	Nucleated	Mixture	18	198	No

COMPARATIVE ASSESSMENT FOR TOLEDO, OH AND GREATER PEORIA, IL

I. DIURNAL HYDRAULIC VARIATION CURVE

	Greater Peoria	Toledo
Peaking Factor		
PF_A (±2σ) - Spring	1.62 (±0.58)	1.56 (±1.15)
- Summer	0.90 (±0.09)	1.12 (±0.45)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	Yes	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Topography	None	--
Soil Type	None	--
Groundwater Table	Yes	Both Toledo with a high groundwater table, and Greater Peoria with a mixture, exhibited seasonal variations (infiltration).
Number of Pumping Stations	None	--

III. CONCLUSION

- Both systems examined were identified as partially combined sewer systems; flow records included inflow which dominated the spring event; and infiltration resulting from high groundwater systems.

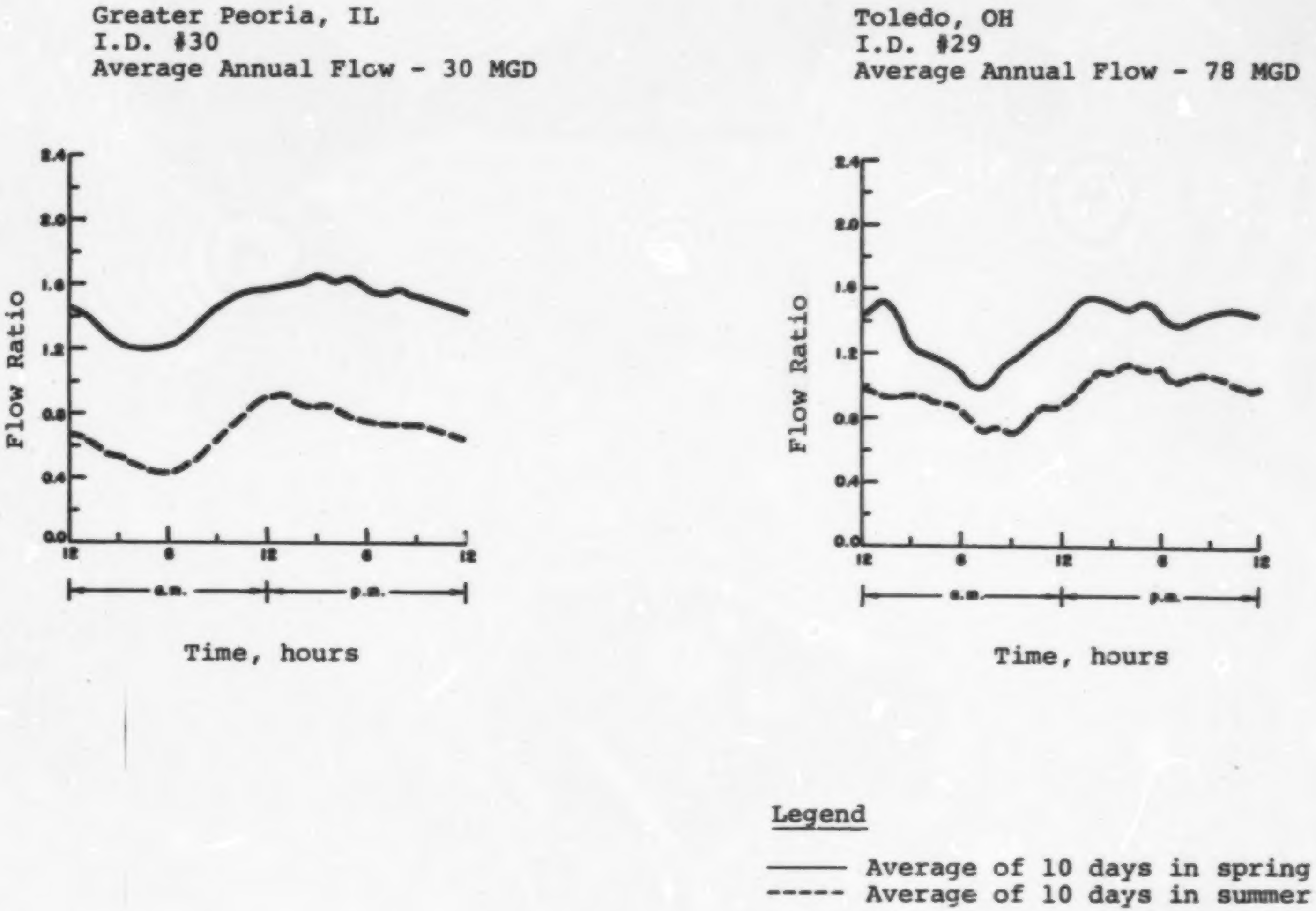


Figure A-22. Diurnal hydraulic variation for I.D. #30 and #29.

COMPARATIVE ASSESSMENT FOR BAYPARK, NY AND BLUE LAKE, MN

I. DIURNAL HYDRAULIC VARIATION CURVE

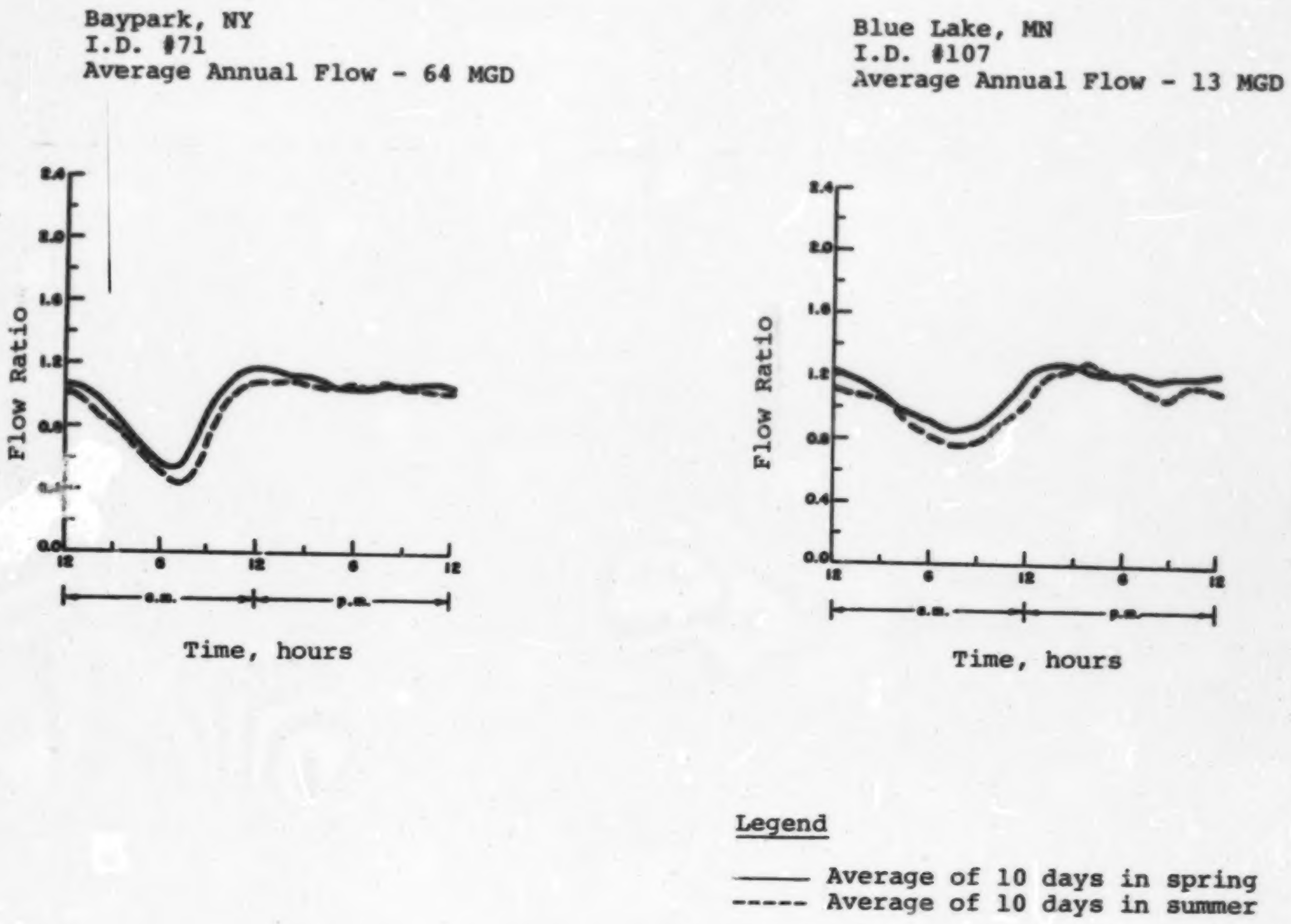
	Baypark	Blue Lake
Peaking Factor		
PF_A ($\pm 2\sigma$) - Spring	1.20 (±0.08)	1.30 (±0.40)
- Summer	1.10 (±0.08)	1.80 (±0.31)
Wave Form - Spring	Typical	Typical
- Summer	Typical	Typical
Seasonal Variation	No	Yes

II. DISSIMILAR COLLECTION SYSTEM PARAMETER IMPACT AND DESCRIPTION

Dissimilar Collection System Parameters	Impact	Description
Average Annual Rainfall	None	--
Topography	None	--
Groundwater Table	None	--
Average Age	None	--
Number of Pumping Stations	None	--

III. CONCLUSION

- The dissimilar collection system parameters such as Average Annual Rainfall (42" versus 27"), Topography (flat versus rolling), Groundwater Table (high versus mixture), Average Age (35 years versus 18 years) and Number of Pumping Stations (21 versus 198) did not significantly influence either the wave form or the peaking factor.



Baypark, NY
I.D. #71
Average Annual Flow - 64 MGD

Blue Lake, MN
I.D. #107
Average Annual Flow - 13 MGD

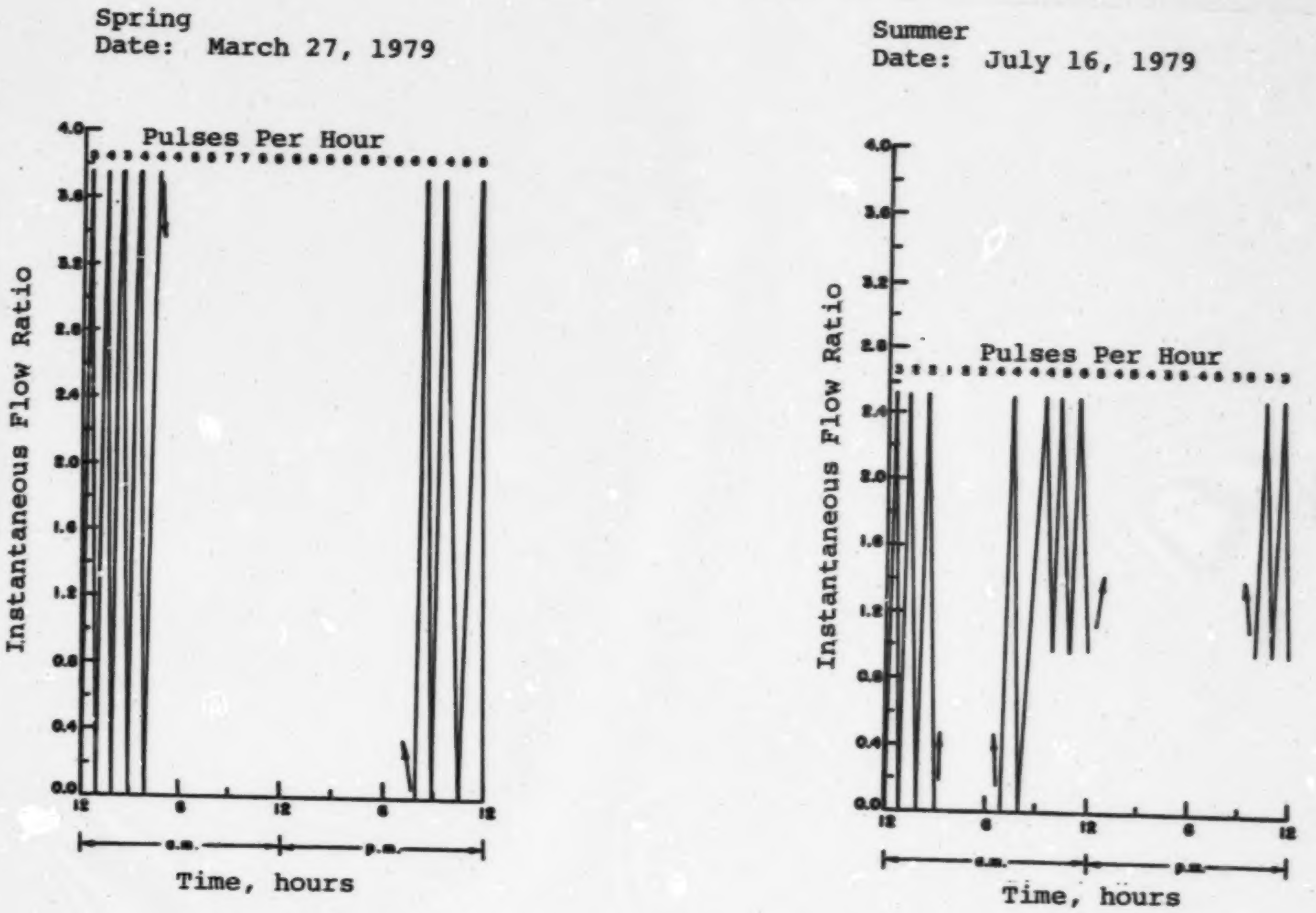
Figure A-23. Diurnal hydraulic variation for I.D. #71 and #107.

APPENDIX B

PUMP DOMINATED SYSTEMS

TABLE B-1. POTW's AND COLLECTION SYSTEM PARAMETERS
PUMP DOMINATED SYSTEMS

I.D. NO.	State	Name	Avg. Annual Flow (Mgd)	Population	Percent Indust. Contrib.	Avg. Annual Rainfall (In.)	Topography	Soil Type	Shape	Ground water Table	Avg. Age (Yrs.)	No. of Pumping Stations	By-Pass
2	NJ	Hightstown	0.84	6,500	12	43	Flat	Sand	Cluster	Shallow	48	3	No
28	OH	Lebanon	1.40	9,500	0	32	Rolling	Mixture	Nucleated	Deep	33	0	Yes
47	CA	San Luis Rey WWTP	3.60	33,000	15	12	Rolling	Sand	Nucleated	Deep	49	13	No
75	NY	Long Beach	6.90	34,300	≤5	38	Flat	Sand	Narrow	Shallow	70	3	No
76	NY	West Long Beach	0.72	5,000	0	38	Flat	Sand	Narrow	Shallow	50	3	No
95	NY	Huntington STP	1.86	19,000	≤5	42	Moderate	Mixture	Cluster	Shallow	62	0	No
131	MO	North Kansas City	3.50	6,950	90	37	Flat	Sand	Cluster	Deep	50	2	No
140	WI	Beloit	6.50	36,000	60	33	Moderate	Sand	Nucleated	Deep	25	11	No


Spring
Date: March 27, 1979

Summer
Date: July 16, 1979

Figure B-1. Pump Dominated System: Typical diurnal hydraulic variation Hightstown, NJ, I.D. #2, Average Annual Flow: 0.84 MGD.

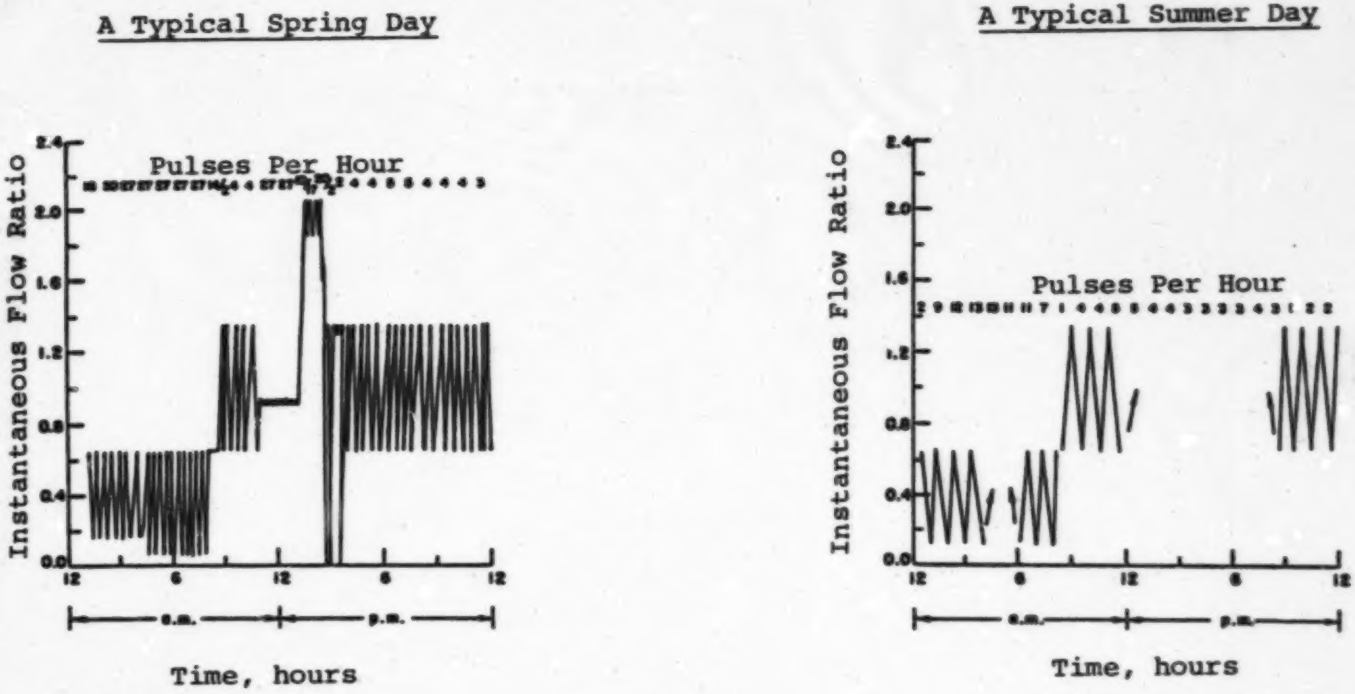
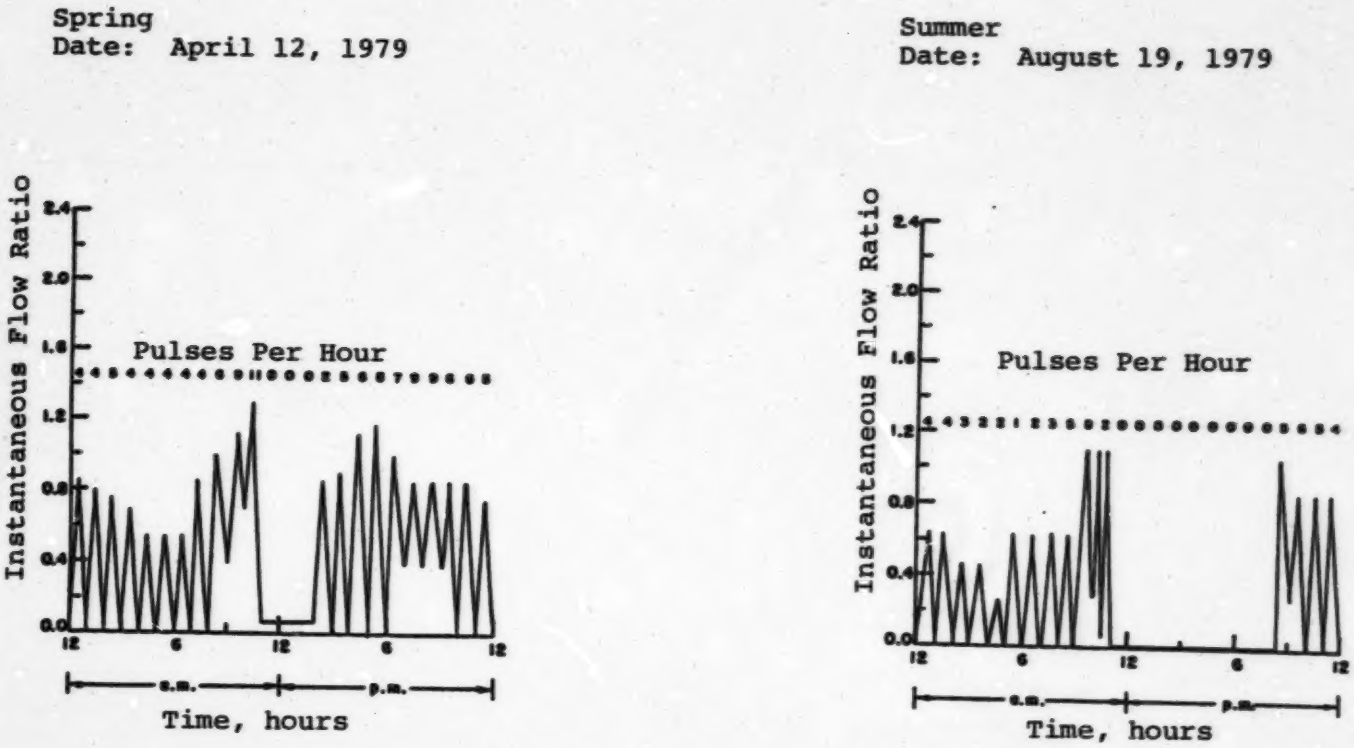
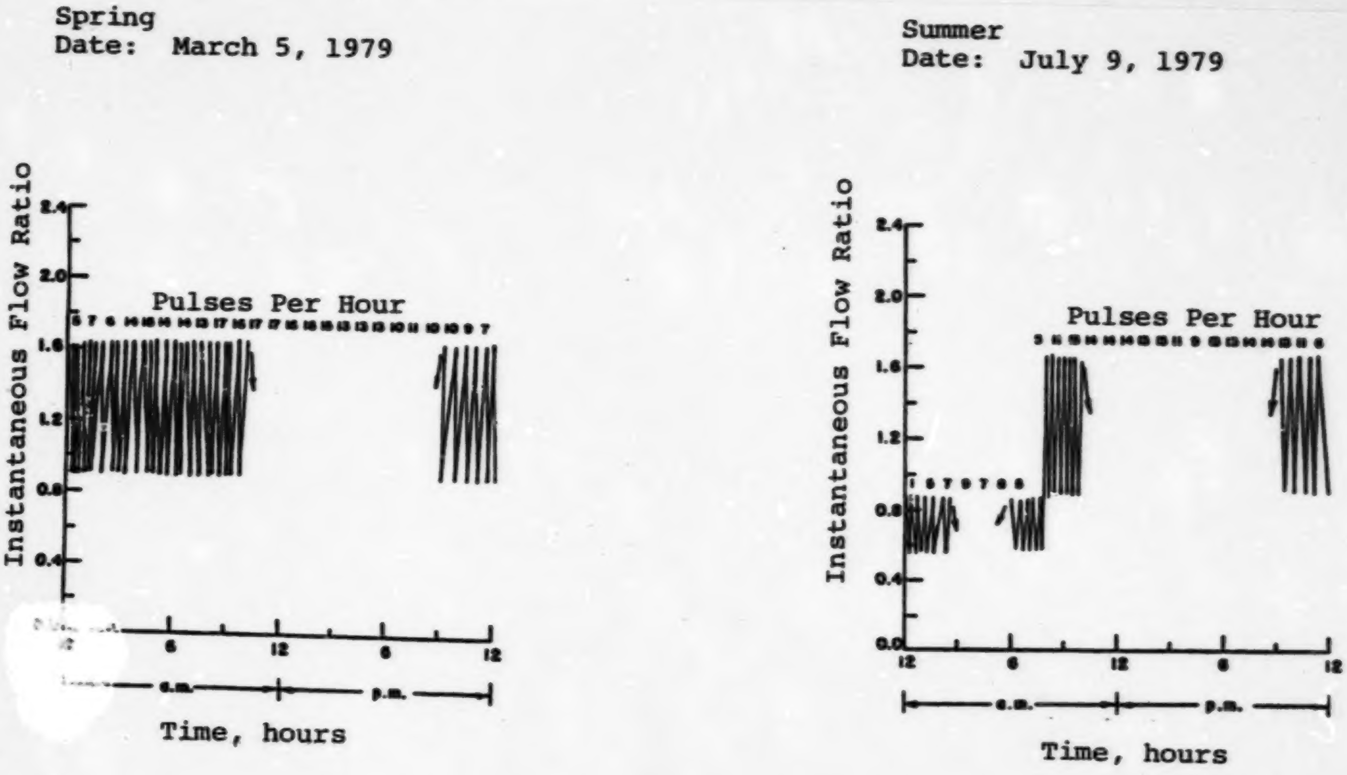


Figure B-2. Pump Dominated System: Typical diurnal hydraulic variations Lebanon, OH, I.D. #28, Average Annual Flow: 1.4 MGD.


Spring
Date: April 12, 1979

Summer
Date: August 19, 1979

Figure B-3. Pump Dominated System: Typical diurnal hydraulic variations San Luis Rey, CA, I.D. #47, Average Annual Flow: 3.6 MGD.



Spring
Date: March 5, 1979

Summer
Date: July 9, 1979

Figure B-4. Pump Dominated System: Typical diurnal hydraulic variations Long Beach, NY, I.D. #75, Average Annual Flow: 6.7 MGD.

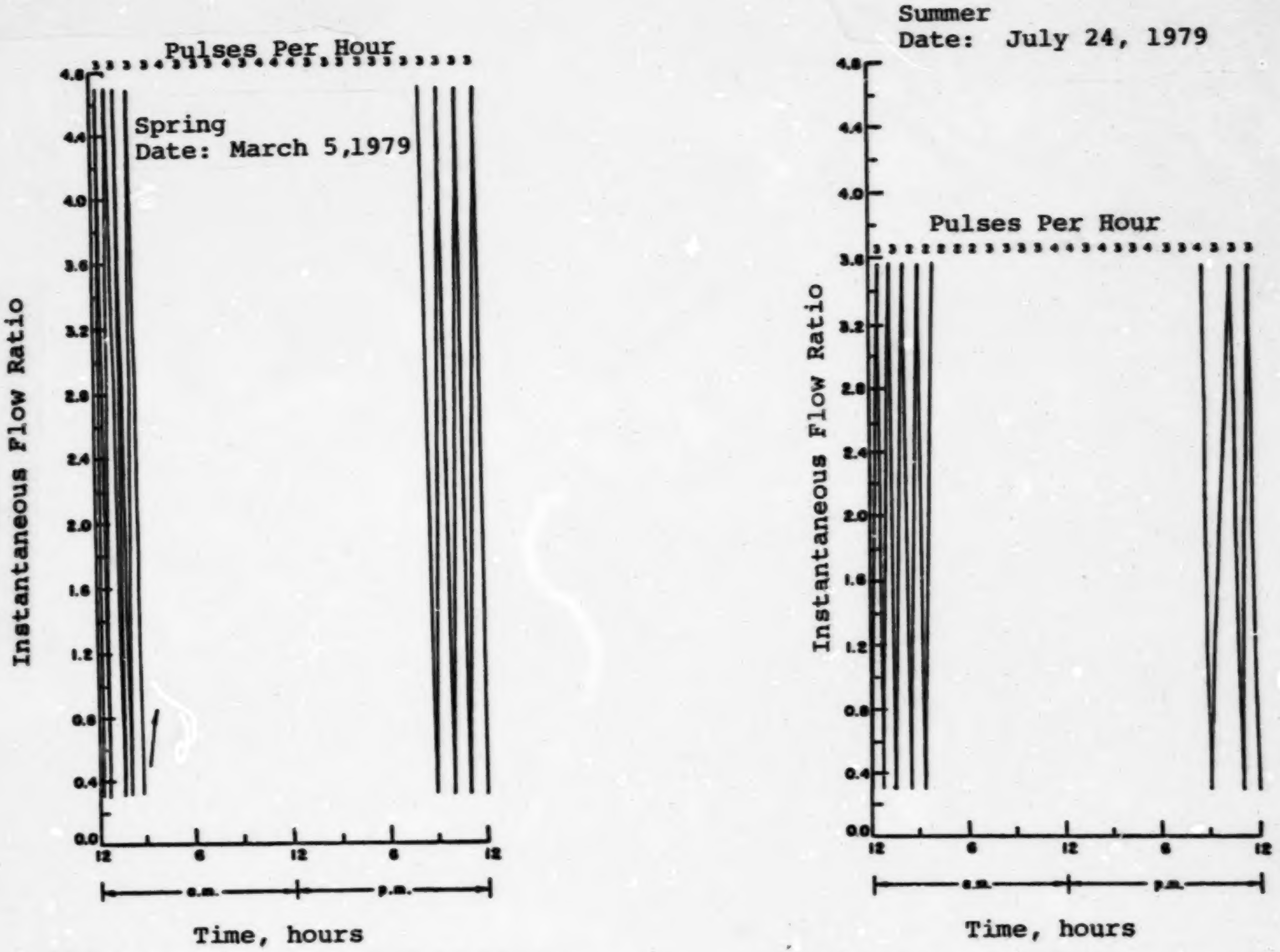
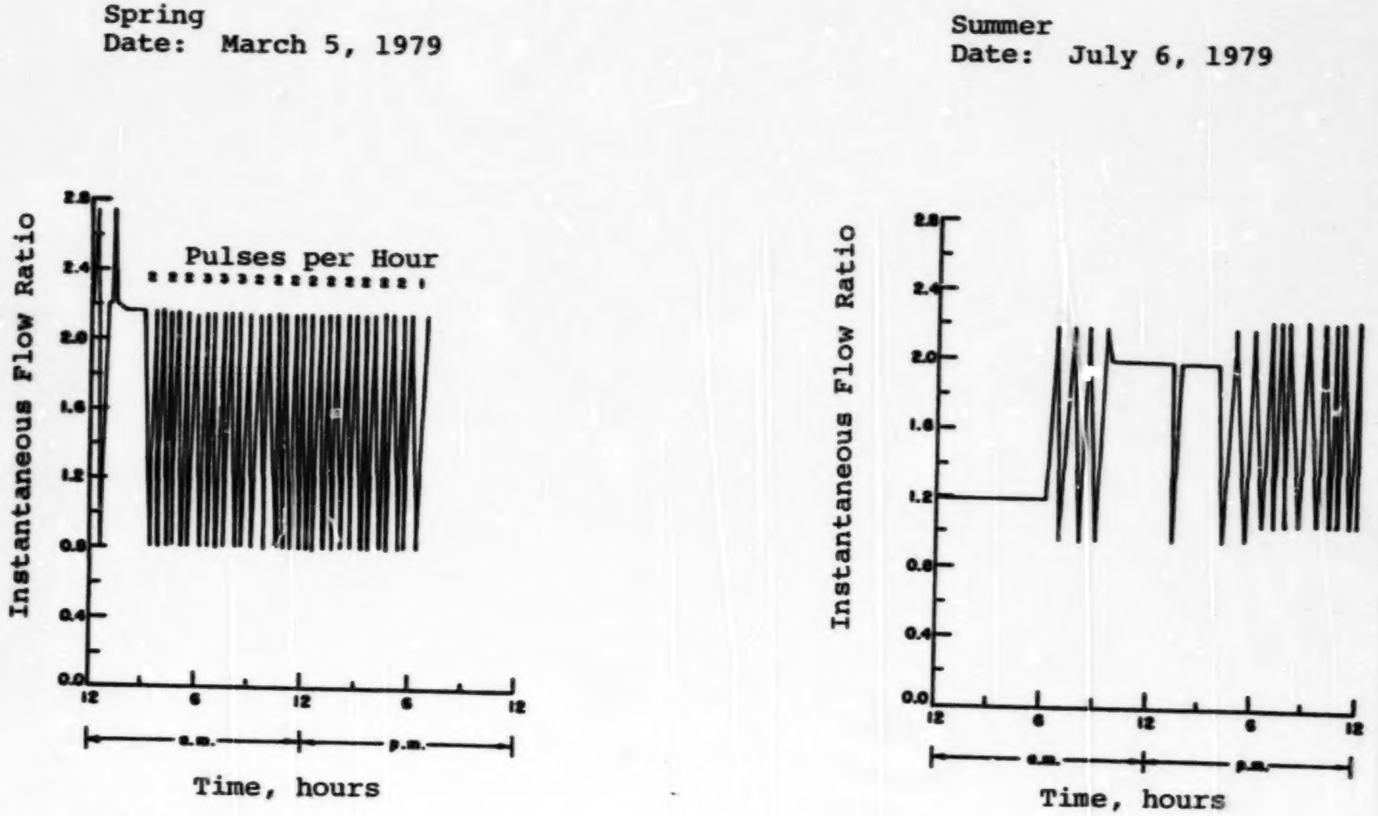
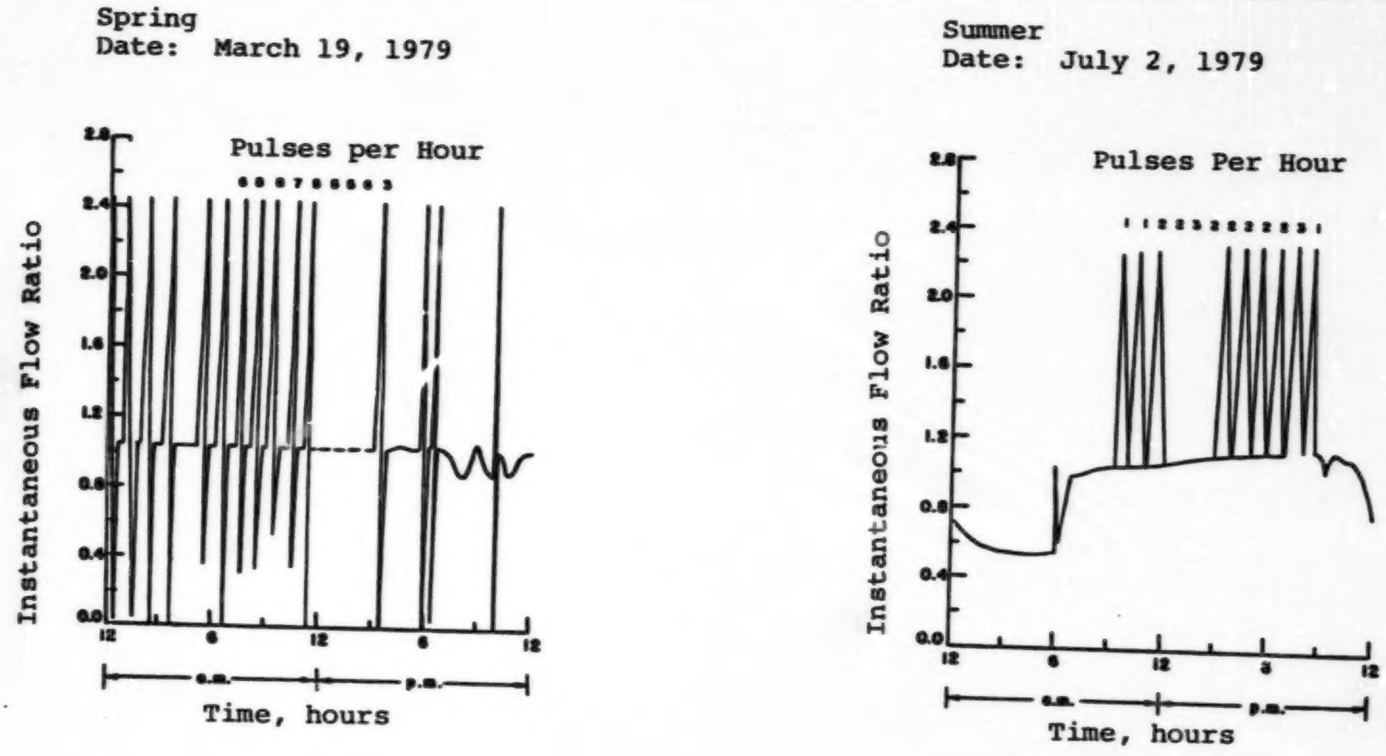


Figure B-5. Pump Dominated System: Typical diurnal hydraulic variations W. Long Beach, NY, I.D. #76, Average Annual Flow: 0.7 MGD.


Spring
Date: March 5, 1979

Summer
Date: July 6, 1979

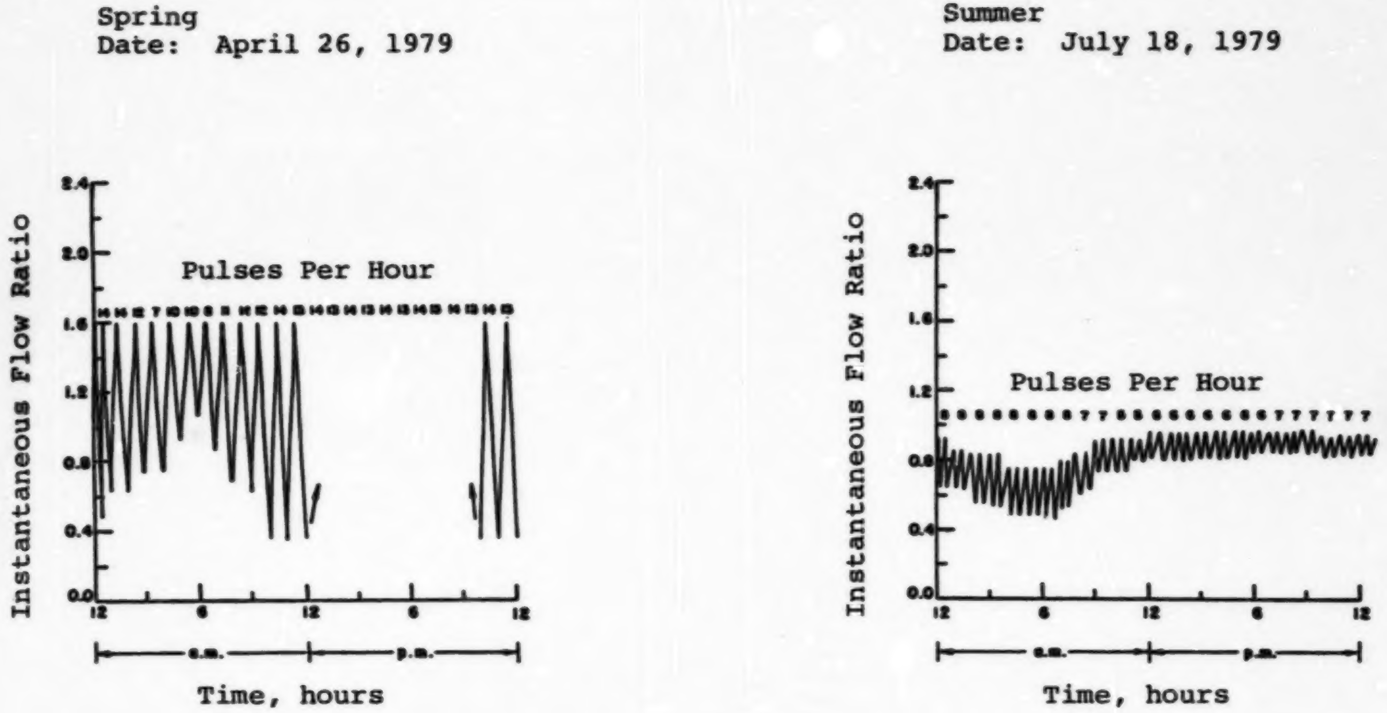
Figure B-6. Pump Dominated System: Typical diurnal hydraulic variations Huntington, NY, I.D. #95, Average Annual Flow: 1.8 MGD.



Spring
Date: March 19, 1979

Summer
Date: July 2, 1979

Figure B-7. Pump Dominated System: Typical diurnal hydraulic variations North Kansas City, MO, I.D. #131, Average Annual Flow: 3.5 MGD.



Spring
Date: April 26, 1979

Summer
Date: July 18, 1979

Figure B-8. Pump Dominated System: Typical diurnal hydraulic variations, Beloit, WI, I.D. #140, Average Annual Flow: 6.5 MGD.

GLOSSARY

annual average daily flow: The total annual volume of influent wastewater to a treatment facility divided by 365 days; commonly expressed in terms of million gallons per day (mgd).

annual peaking factor: The peak flow during a specified peaking duration, peaking period, and sample time period by the annual average daily flow.

average age: The estimated average age of the collection system.

average peak hourly flow: The sum of maximum daily flows in a given sample divided by the number of days in that sample when flow measurement is made at least hourly.

average sample time period flow: The total volume of influent wastewater to a treatment facility during a specified sample time period divided by the number of days in the sample time period.

average value: The sum of values in a given sample divided by the number of values in the sample.

collection system parameters: Identified for this investigation to be annual average daily flow, population, industrial contribution, average annual rainfall, topography, soil type, shape of collection system, groundwater table, average age, and the number of pumping stations and bypasses.

combined sewer system: A sewerage system which conveys sanitary and stormwater flows in the same pipes.

dissimilar collection system parameters: Collection system parameters which differ between two collection systems.

flow ratio: The ratio of actual flow divided by average flow, where both flows are measured in the same units such as mgd.

infiltration: The excess flow (in addition to sanitary flow) in a collection system resulting from a high groundwater table and its subsequent leakage into sewers.

inflow event: An outside occurrence (normally a rainfall) which induces excess flow (in addition to sanitary flow).

maximum value: The highest single value in a given sample.

minimum value: The lowest single value in a given sample.

peak flow: A maximum flow which is defined by a peaking duration, peaking period, sample time period, or sample analysis.

peak hour: The hour of the day in which the peak flow occurs.

peaking duration: A unit of time over which the peak flow is being measured (e.g., instantaneous peak, 15 minutes, peak hour).

peaking factor: The ratio of the peak flow divided by the average flow, where both flows are measured in the same units such as mgd.

peaking period: The time interval over which the peaking duration is being monitored (e.g., peak hour/day, peak hour/year).

POTW: Public owned treatment works.

sample analysis: An analysis of data obtained during a sample time period to obtain the average, maximum, or minimum value of the data.

sample peaking factor: A peak flow observed during a sample time period divided by an average sample time period flow.

sample time period: The interval of time from which the data is obtained.

sanitary flow: Collection system flow resulting from normal domestic activities.

separate sewer system: A collection system with segregated sanitary and stormwater sewers.

significant collection system parameters: Collection system parameters which produce notable effects on peaking factors and diurnal flow patterns.